DISASTER MANAGEMENT AND RESPONSE:

A LIFELINES STUDY FOR THE QUEENSTOWN LAKES DISTRICT

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ABSTRACT

The Queenstown Lakes District is vulnerable to a number of natural hazards. These include earthquakes, mass movements, meteorological hazards and flooding. Many of the hazards that threaten the district have the potential to cause loss of life or injury and all of them have the potential to cause severe damage to homes, businesses and other infrastructure.

Infrastructure and services that support life and business in the community, and that are used everyday are known as lifelines. Lifelines are generally taken for granted but are directly associated with the quality of life that we live. Lifelines include electricity, telecommunication, water supply, wastewater removal, transportation and emergency services.

Following a major disaster the need for safe, effective and timely restoration of these lifeline systems is critical. This project analyses the vulnerability of lifelines with respect to natural hazards with the aim that it can be used to ensure that when a disaster occurs appropriate and efficient action is taken to minimise the impact.

This thesis also attempts to raise awareness and understanding of the hazards that threaten the Queenstown Lakes District as well as emphasise the importance of lifelines and what's involved in their management. This will hopefully help readers understand the likely impacts of a disaster so that when one occurs they will not be completely caught unaware. This thesis will also hopefully entice the reader to better prepare for a disaster.

Scenarios of each hazard were created based upon current scientific understanding and are used to illustrate more clearly the priorities that need to be addressed during the response and recovery phases of a disaster.

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CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND

Over the last three decades the number of disasters occurring globally has more than tripled. However, the frequency of dramatic natural events has remained fairly constant (United Nations, 2004). The reason why disasters are increasing whilst the number of natural events has stayed the same can be attributed to human activities and the fact that people are placing themselves in more vulnerable situations.

It is important to define the terms hazard, disaster and vulnerability. A hazard refers to the possibility of a physical event causing injury or loss of life and the potential for property damage, social and economic disruption. Hazards come in a variety of forms and can be categorised as natural or technological.

- Natural hazards are events that occur naturally in the environment. There is generally no way of stopping them. These include meteorological hazards (e.g. cyclones, floods), geological hazards (e.g. earthquakes, landslides) and biological hazards (e.g. epidemics).

- Technological hazards are events that have an element of human intent, negligence or error associated with them (e.g. industrial accidents such as the release of hazardous substances, structural collapses such as buildings or bridges). These hazards can generally be avoided with the implementation of appropriate plans and procedures.

Disasters are the actual consequences or effects of these physical events (i.e. a hazard alone is not a disaster. The hazard has to impact a community or a populated area before it can have disastrous effects). For example, a tsunami travelling over open water is not a disaster but when it strikes a population located on a coastline, the results can be disastrous.

Vulnerability refers to the susceptibility of people, communities and regions to hazards. Vulnerability can be influenced by many factors such as location, building standards, the level of preparedness and the ability to evacuate and carry out emergency operations. Different communities can have different levels of vulnerability; this is one reason why hazards of a similar type and intensity can have quite varied effects on different areas and why plans need to be made for each individual community.

The impact of a natural event depends on a community's vulnerability and because of the increasing global population, communities are becoming more widespread and more densely populated thus exposing more people to the hazard of natural events. Global climate change is also increasing the number of potential disasters, in part due to rising sea levels and more extreme weather related events.

In recent years there have been a number of large scale disasters that have struck vulnerable communities in different parts of the world. Examples of these events include the Indian Ocean Tsunami in 2004, Hurricane Katrina and the Bangladesh floods in 2005 and the Sichuan Earthquake in 2008. This has resulted in huge devastation, large numbers of victims and incomprehensible damage to local economies where decades of development have been wiped out in a matter of seconds. The types of hazards that triggered these disasters have varied from the seemingly unexpected occurrence of earthquakes, to more predictable seasonal floods and periodic storms. If nothing more, the media images (figure 1.1) of these events have reaffirmed the need for people to be more aware and better educated regarding hazards; the impacts, specific mitigation measures and how to increase resilience of the community, the nation and the infrastructure to disasters.

Figure 1.1: Collage of Recent Natural Disasters. Landslide in Central America (top left) Earthquake in China (top right) Indian Ocean Tsunami (bottom left) Hurricane Katrina (bottom right)

1.2 DISASTER MANAGEMENT

Over the last few decades, there has been a continuous evolution in the practice of disaster management. Disaster management revolves around the concept of the 4 R's; Reduction, Readiness, Response and Recovery (figure 1.2). The traditional focus has been on the reduction and readiness phases of the cycle where governments have implemented preparation strategies (e.g. CDEM plans) as well as operational capacities (e.g. civil defence) for more timely and effective response to an impending event.

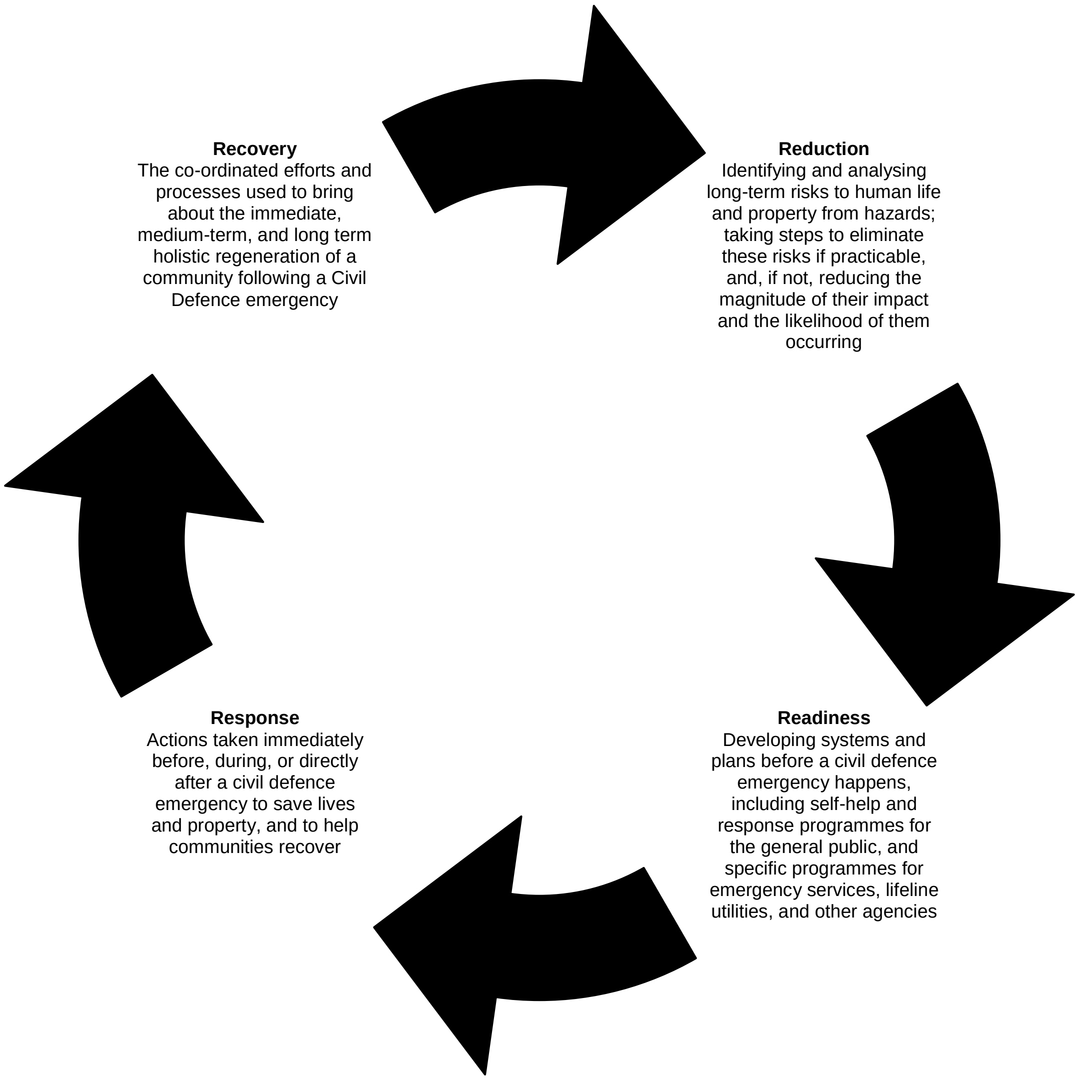


Figure 1.2: Disaster Management concept of the 4 R's (Source: Civil Defence Emergency Management Act, 2002)

There is no doubt that the role of relief assistance during the response phase of a disaster will remain important. However it is now more widely accepted that people should not rely on emergency services and Civil Defence in the aftermath of a major event because in reality the demand is likely to be so overwhelming for all agencies that it may take days before anyone responds. Therefore, as a result, disaster management has changed direction and now governments are trying to educate the public on the risks from the environment and what can be done to survive a disaster.

This initiative has been endorsed by local councils, a range of businesses and some of the public who are – perhaps motivated at least partially by the frequency and severity of natural disasters during the past decade – progressively recognising the value of sustained efforts to reduce the impacts of natural hazards. However there are still many people who don't understand the risk from natural events particularly at a local level. These people are either unaware of the risks or are ignorant of the likely effects (i.e. they probably believe that an event of large magnitude won't occur in their lifetime or they will manage it when the time comes).

Risk awareness depends largely on the quantity and quality of available information and on the difference in people's perceptions of risk. Perceptions of risk differ between individuals as it is generally influenced on past experiences and knowledge. People are more vulnerable when they are not aware of the hazards that pose a threat to their lives and property. This thesis attempts to increase the awareness of natural hazards in the Queenstown Lakes District so that when a disaster occurs people will understand the impact it will have on the districts lifelines.

1.3 LIFELINE STUDIES

Lifelines are infrastructure networks and services that support life and business in the community. Lifelines include water, power, sewerage, transportation and communication networks and emergency services. Modern society is now more than ever before dependent upon the efficient and continued functioning of these basic services and infrastructure. Lifelines are often taken for granted, and their importance under-appreciated. This is not helped by the fact that many lifelines are underground or are out of view from the public (Dunedin Lifelines Report, 2006).

The study of lifelines has become an essential element of disaster management since the United States of America commissioned a nationwide assessment of lifeline vulnerability in 1988 after being disturbed by continued seismic activity. The work was completed in 1991 and received positive reviews from around the world (Post-earthquake fire and lifelines workshop, 1995).

In New Zealand, the study of lifelines was initiated by the Centre of Advanced Engineering (CAE) at the University of Canterbury. CAE undertook a seismic assessment of lifelines in the capital city of Wellington and published their "Wellington Case Study" in August 1991. Since then a number of other major cities and some smaller towns in New Zealand have also carried out lifeline assessments including Christchurch in 1994 and Dunedin in 1996. However, as research into the discipline has increased so too has lifeline assessments with most studies now extending beyond the pure seismic vulnerability to cover hazards such as flooding, landslides and technological hazards.

1.4 PROJECT AIMS AND OBJECTIVES

The aim of this project is to raise awareness and understanding of the hazards that threaten the Queenstown Lakes District and emphasise the importance of lifelines. This study will also determine lifeline vulnerability to ensure that when a disaster occurs appropriate and efficient action is taken to minimise the impact.

The overall objectives of the Queenstown Lakes District Lifelines Project are:

- To identify hazards within the Queenstown Lakes District and to discuss the processes involved in their development.
- To study the risks posed to lifelines (water, power, sewerage, transportation and communication networks and emergency services) servicing the Queenstown Lakes District from various hazards.
- To recognise interdependencies, identify strategies and determine priorities for reducing the impact and restoration time of lifelines following such events.
- To create a scenario-based plan that will give a clearer understanding of where the key risk areas are, what services can be expected to fail during different disasters and what recovery times can be expected.
- To communicate the issues to those involved in the management of these services and to raise public awareness of their importance.

1.5 PROJECT METHODOLOGY

The Queenstown Lakes District is susceptible to a wide variety of hazards including earthquakes, flooding, mass movements, meteorological hazards, biological hazards and technological hazards. However, this project primarily focused on those hazards that pose a substantial risk to lifelines. These include earthquake phenomena (such as ground shaking, liquefaction, fault displacement and seiche effects), flooding, mass movements and meteorological hazards (i.e. natural hazards).

Biological hazards such as pandemics, although discussed briefly, were not included in the analysis. Biological hazards do not pose a great enough threat to lifelines and including biological hazards into this project would have detracted the thesis from its overall aim. Technological hazards (such as fires, transport accidents, chemical exposure, infrastructure failure and terrorism) present a risk to lifelines, however, their source and surrounding risk area can be difficult to define, particularly due to the unpredictable nature of human malfeasance and mechanical failures. Therefore, because of the highly variable nature of these hazards and the fact that in isolation they can be managed effectively within current company procedures, technological hazards have not been discussed in detail within this thesis.

In general, this project follows the well-proven methodologies and procedures that were used in previous engineering lifelines studies such as those that were developed for the major metropolitan centres of Auckland, Wellington, Christchurch and Dunedin. There are several concepts in this thesis that have been modified from past studies:

1. The information contained within this thesis has been designed for the general population, so if this thesis is published, people particularly the public should find it interesting and understandable. In order for this to be achieved the following ideas have been employed:
    - Detailed descriptions of the hazards and lifelines within the district have been written to ensure that the reader fully understands the nature of the hazard and the function of lifelines.
    - Lifeline vulnerabilities have been assessed using qualitative analysis to reduce the need of evaluating risk assessment tables.
    - To better illustrate the needs and priorities of the community scenarios have been created for each hazard. The purpose of a scenario is to draw the reader in by incorporating familiar aspects of the community that can be readily recognisable so that they fully understand the nature of the hazard.
2. The underlying theme of this thesis is response and therefore will discuss in more depth the roles that organisations (e.g. police, fire, ambulance services) will play in the event of a disaster and the likely procedures that will need to be carried out.

Information gathering techniques were used to gather information about the study area including history, location, geological and geomorphological setting and climate.

Scientific research was carried out in the area to identify the hazards that might impact upon the region. Qualitative assessments were made of vulnerabilities to given hazards, and the consequences of the damage. Where possible data was digitised and GIS layers produced to enable the printing of hazard maps. These are reproduced at the end of the thesis. Data was supplied courtesy of the Institute of Geological and Nuclear Sciences and the Queenstown Lakes District Council.

The project aimed to identify, describe and map the major lifelines that support the area in order to assess the vulnerability to a number of natural and technological hazards. Lifeline managers were asked to describe the network in terms of its purpose, location, processes, management and day to day vulnerabilities. Vulnerabilities of the lifelines were assessed using appropriate network maps that could be overlaid with the hazard maps to identify areas of higher risk. The network was then divided into components and a full description and analysis was written in order to predict the type and extent of the damage to each component by exposure to hazard. Lifeline management including mitigation options, typical responses and restoration times came under review. The importance of interdependence of services was also considered.

Scenarios were created based upon current scientific understanding of each of the hazards and information gained through the investigation of lifelines. The scenarios are not in anyway intended to predict what would actually happen. Rather, it gives a plausible and feasible picture of a possible disaster simply to better illustrate the needs and priorities of the community during a time of crisis.

1.6 THESIS FORMAT

This thesis is divided into seven chapters: Introduction, Regional Setting, Hazard Overview, Lifelines, Scenarios, Discussion and Review, and Summary and Conclusions.

Chapter one gives an overview of the project including aim, objectives and methodology. Also included within this chapter is background information on disaster management principles and past lifeline studies.

Chapter two gives an insight into the study area by discussing the geological setting, geomorphology and landscape development as well as a brief introduction of communities within the district.

Chapter three provides information on the hazards that threaten the Queenstown Lakes District and the possible effects to promote further understanding.

Chapter four provides information on the lifelines in the Queenstown Lakes District, including a brief description of the service and their vulnerability to, and management of specific hazards.

Chapter five describes a realistic scenario of each hazard including explanations on the most likely effects based on current scientific understanding.

Chapter six discusses disaster management implications and the final chapter outlines the conclusions made in this project and summarises the concept of interdependency and response priorities.

CHAPTER TWO
REGIONAL SETTING

2.1 INTRODUCTION

The Queenstown Lakes District is located at the southern end of the South Island, on the eastern flanks of the Southern Alps of New Zealand (figure 2.1). East-west through the middle of the district is latitude 45 degrees south, the halfway line between the equator and the South Pole. World renowned for its beauty and scenery the Queenstown Lakes District is characterised by such industries as film production, wine making and tourism (Peat et. al., 2005).

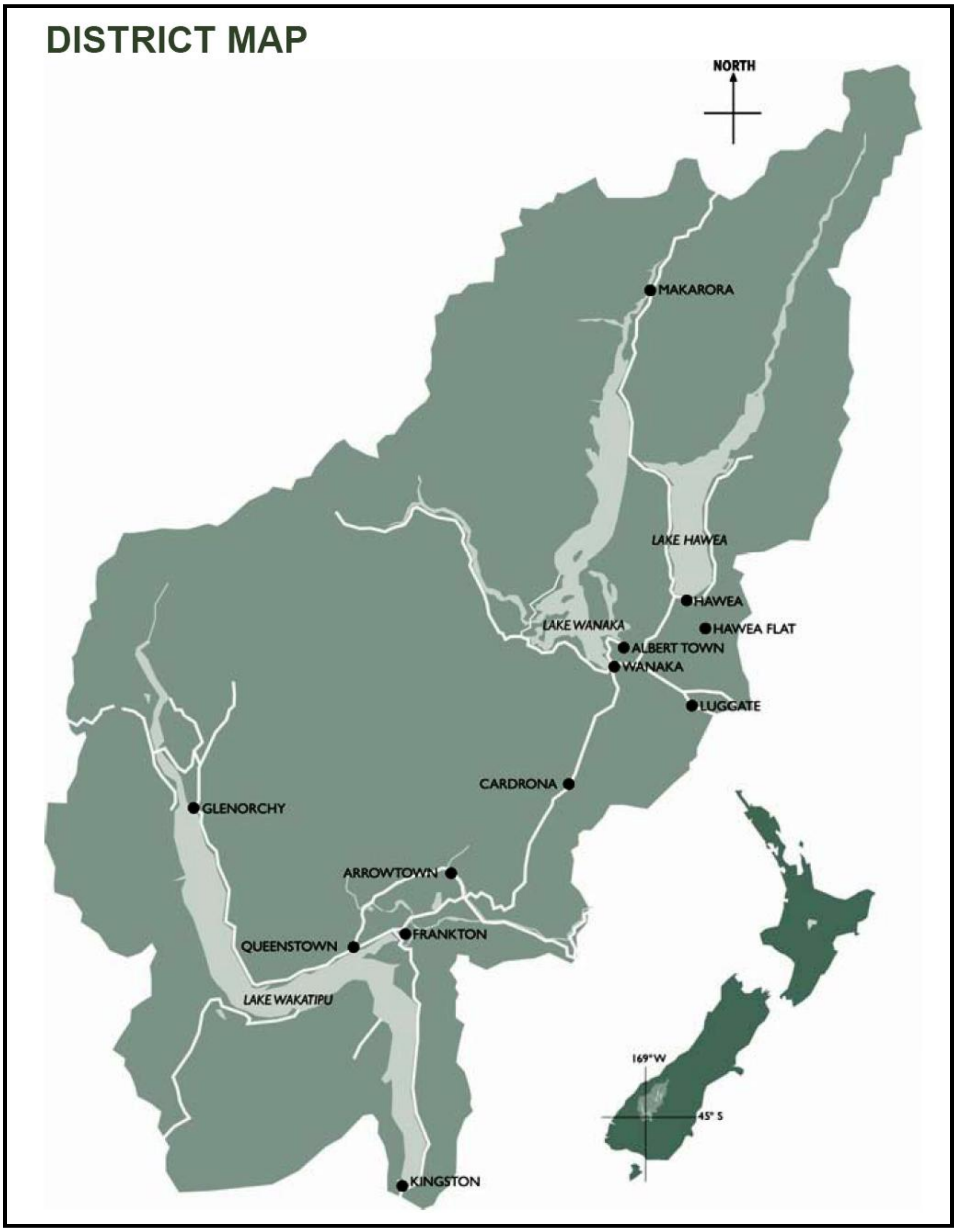


Figure 2.1: Map of the Queenstown Lakes District (Source: Council Community Plan)

At the northern tip of the district are the heads of Lakes Wanaka and Lake Hawea. The eastern edge of the district is marked by the Pisa range. The Eyre Mountains mark the southern tip and the head of Lake Wakatipu is way out west. These points enclose an area of approximately 8,000 square kilometres where people from around the world come to relax, experience new thrills and to attempt new challenges. The Queenstown Lakes District has a resident population of around 23,000, swelling to 45,000+ people in peak visitor periods (Statistics New Zealand, 2007).

There are twelve major townships and a number of smaller communities in the Queenstown Lakes District. The whole region revolves around the largest townships in the district Queenstown and Wanaka. For more than a century, the beautiful alpine scenery has inspired visitors from around the world and consequently, the region is experiencing a major phase of development which is exerting pressure on the available land, and as a result, more and more people are becoming vulnerable to the hazards that this beautiful landscape presents.

The district can essentially be divided into two sub-regions based upon geography and the location of services, the Lake Wakatipu region and the Lake Wanaka and Hawea region. The following brief descriptions illustrate the location, access routes and demographics of each community. This background information may prove useful during a disaster when preparing specific response plans, as it will give a rough idea of how many people it may involve and what resources may be required.

2.1.1 LAKE WAKATIPU

The Lake Wakatipu region includes those communities situated around Lake Wakatipu (Kingston, Queenstown and Glenorchy), as well as the townships of Arrowtown, Arthurs Point and Lake Hayes. These communities generally revolve around the largest township in the district Queenstown.

- ***Kingston***

  Kingston lies at the southernmost end of Lake Wakatipu, 48km south of Queenstown between the Eyre and Garvie mountains. Kingston marks the southern gateway into the Queenstown Lakes District. Kingston can either be reached from the north via the Kingston Road or from the south via the Garston – Athol highway (SH6). Kingston is home to about 600 people and the restored vintage steam train known as 'The Kingston Flyer.' This premier attraction operates from October to April carrying visitors on a memorable scenic journey to Fairlight and back. In its heyday (1878), this line was considered to be one of the most important in New Zealand and ran between Kingston and Invercargill via Winton.

- ***Queenstown***

  The township of Queenstown is situated on the eastern shore of Lake Wakatipu in a naturally formed bay on the middle arm of Lake Wakatipu (figure 2.2). Immediately north-east of the central business district the land rises steeply to Queenstown Hill. To the north-west and the north are the flanks of the Ben Lomond Range and Bowen Peak. Between Queenstown Hill and Bowen Peak a valley gives access to the Shotover River. The outlet of Lake Wakatipu (Kawarau River) is located to the north-east at the foot of the gently sloping alluvial fans of the Shotover River. Situated on these fans is the suburb of Frankton.

Figure 2.2: Panoramic view of Lake Wakatipu with the Queenstown Township in the foreground (Photographer: Paul Hansen)

Across the lake, Cecil and Walter Peaks rise from the waters edge. Development over the last 30 years has seen the residential area expand rapidly to the west and east along the lower slopes bordering the lake and Frankton Arm. The township has a resident population of about 9,000 which can more than double during peak tourist seasons.

- ***Arrowtown***

  Arrowtown is situated close to the western bank of the Arrow River in an area of small hills and flats between the head of the Frankton arm of Lake Wakatipu and the western slope of the Crown Range. Surrounded by mountains, Arrowtown is 18km northeast of Queenstown and is reached either via Arthurs Point down Malaghans Road or by a side road turning off the Queenstown-Cromwell highway near Lake Hayes.

Arrowtown's focus is on tourism offering shopping, accommodation, restaurants, sightseeing and numerous recreational pursuits in its restored historic precinct. Many of the gold miners’ cottages, historic wooden buildings and 19th century-style shops have been preserved and are still standing as they did during the gold rush. Arrowtown still provides limited services for its 1,600 residents and nearby farmers.

- ***Glenorchy and Kinloch***

  Glenorchy is a small settlement nestled in spectacular scenery on the edge of two of New Zealand's greatest national parks; Mount Aspiring and Fiordland National parks, at the northern end of Lake Wakatipu (figure 2.3). It is approximately 45km northwest of Queenstown and lies at the meeting point of a gravel fan delta built by the Buckler Burn River on the eastern lake margin, and the southward protruding delta and plain built by the combined Dart and Rees Rivers. The only access into and out of the town is via a single road the runs along the eastern shore of Lake Wakatipu.

Figure: 2.3: Panoramic view of Glenorchy (Photographer: Paul Hansen)

  Glenorchy is a village with just over 200 people and Merino sheep stations blanket the land. It is an area that is world renowned for its walking tracks and tourists, particularly trampers come from all over the world to experience this spectacular scenery. Directly across the Dart River fan and 26 km around the head of the lake along an unsealed road lies the tiny town of Kinloch; a village with a population of under a dozen residents.

2.1.2 LAKE WANAKA AND HAWEA

The Lake Wanaka and Hawea region includes those communities situated around the Lake Wanaka and Hawea (Wanaka and Hawea), as well as the townships of Cardrona, Luggate, Albert Town, Hawea Flat and Makarora. These townships generally revolve around the second largest township in the district Wanaka.

- ***Cardrona***

  Cardrona is a small township in a rugged rural setting located between Queenstown and Wanaka along the Crown Range Road. It is a very popular winter destination and is home to three ski fields that are world renowned for skiing and snowboarding. The township is growing vastly and already consists of a hotel and bar as well as a number of restaurants and a shop. The resident population of Cardrona sits at approximately 200 people.

- ***Wanaka***

  The Township of Wanaka is located at the southern end of Lake Wanaka, 120km northwest of Queenstown. The town is situated adjacent to the outflow of the lake into the Clutha River and, like Queenstown, it is surrounded by mountains (figure 2.4). Developments in and around Wanaka have doubled over the last 10 years and are continuing to grow. Development has forced parts of the town onto the hills that surround the central business district which is located on the flat lying, flood prone land south of Lake Wanaka.

  Wanaka has a permanent population of around 5000 which increases to about 7000 during the height of winter and summer. Wanaka can be reached from the north via Haast Pass that cuts through the Southern Alps near the township of Makarora or from the south either via the Crown Range Road from Queenstown or by travelling through Luggate.

Figure 2.4: Panoramic View of Lake Wanaka with the Wanaka Township in the foreground (Photographer: Glen Coates)

- ***Hawea***

  To the east of Lake Wanaka in a parallel glacial valley there is also another settlement called Hawea. With a population of about 1,500, the centre of the town is situated on flat, floodwater at the head of the lake.

- ***Makarora***

  Makarora is situated at the head of Lake Wanaka and marks the north-western boundary of the Queenstown Lakes District.

2.2 CLIMATE

The climate in the Queenstown Lakes District has average annual temperatures ranging from 3°C to 16°C. Summer, from December through to February are the warmest months of the year with typical daytime maximum air temperatures ranging from 20°C to 26°C, occasionally rising above 30°C. Winter, from June to August, is very cold with frequent, often severe frosts, and occasional snowfalls. Typical winter daytime maximum air temperatures range from 3°C to 11°C. Air temperatures during winter can fall as low as -6°C. Highest rainfall generally occurs during winter months (NZ Met Service, 2007).

The regional climate can have a major influence on the extent of the disaster. Not only is the climate the source for many of the disasters that are discussed in this thesis, but it also has a profound impact on the way emergency services respond to an event. For example, restoration times of some services may be prolonged due to the fact that repairs can only be made when it is safe to do so; generally after the original event has dissipated (e.g. strong winds). If the event occurs in winter, snow and ice may hamper relief efforts and the cold temperatures will intensify the need for rapid evacuation of the injured.

Ski-fields present an additional vulnerability to relief efforts because if an event such as an earthquake occurs during a time when ski fields are in operation, thousands of people may become trapped due to avalanches and rockfalls disrupting access. Ski field operators may need to accommodate skiers for a number of days after the event.

2.3 TOURISM

The Queenstown Lakes District is without a doubt New Zealand’s most popular tourist destination. Promoted as an alpine resort for all seasons, with accommodation, activities, attractions and services to suit a range of visitor markets; over 1.4 million people each per year visit the region. 65% of these are international visitors (Queenstown Lakes District Council, 2008). It should be noted that the four seasons each attract a different mix of visitors.

The summer season begins with a strong domestic focus followed by a peak tourism period where visitors from around the world come through to Easter. There is generally a small reduction in numbers from April through to June. From mid June to mid September the visitor market peaks again comprising mostly of domestic and Australian skiers and snowboarders. The spring season through to late October sees a gradual increase in international visitors (Queenstown Lakes District Council, 2008).

Tourism presents a complex situation when it comes to disaster management because it will be important to control the movement of people into and out of the district. In the event of a disaster there will be tourists who want to leave the area as well as those visitors who have come to witness the devastation. This will place additional pressure on emergency services and other resources. To effectively manage a situation it may be advantageous to reduce the amount of people, particularly tourists in the district. This will then elevate some of the pressure on emergency services and other resources. For example with the reduction of tourists, hotels and motels could be utilised to accommodate those people evicted from their homes that have been damaged in the event.

2.4 GEOLOGICAL SETTING

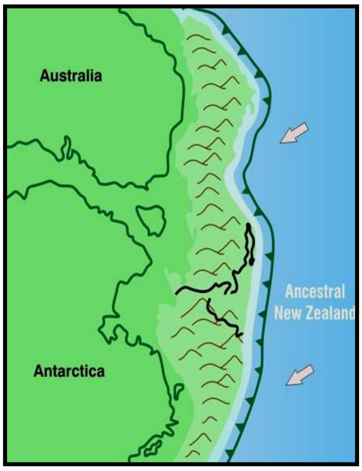
The people who settled New Zealand came to a dramatic and unquiet land, with rugged mountains, active volcanoes and frequent earthquakes. It is a country with a complex geological history. Its bedrock is a geological jigsaw puzzle (Encyclopedia of New Zealand, 2007). An understanding of New Zealand's past and its lively geological activity is essential in order to understand what could be experienced in the future.

The shape, position and relief of the New Zealand landmass is a consequence or response to plate motion. New Zealand owes its existence to the collision of two large tectonic plates. As these plates are thrust together it forces the earth's crust to wrinkle up and deform, developing the landscape that is seen today.

The landscape in the Queenstown Lakes District varies from flat topped ranges and intervening basins to glaciated mountains. Five percent of the land is low lying, comprising of a mixture of fans and terraces with several isolated hills. The rest of the land rises steeply to elevations above 1000m to form the steep mountain ranges that over shadows the region.

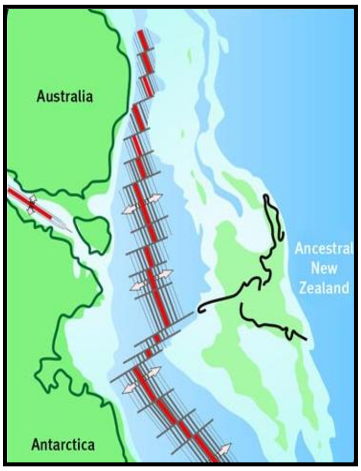
2.4.1 FORMATION AND EVOLUTION

The majority of New Zealand's landmass was formed during the Cambrian through to the Devonian periods, some 540 to 360 million years ago (Hicks et. al., 1998). Located along the eastern margin of the super-continent Gondwanaland (prehistoric landmass that consisted of Antarctica, Africa, Australia, South America and India), the first rocks of New Zealand began forming. These basement rocks that now makeup more than half of the New Zealand landmass are comprised of recycled materials that were eroded from the Australian segment of the Gondwanaland super-continent and transported by river to the ocean where the fluvial sediments mixed with volcanic materials and built up over millions of years. Eventually, tens of thousands of meters of sediment built up, hardened and deformed to become the rocks known as the Torlesse greywackes.



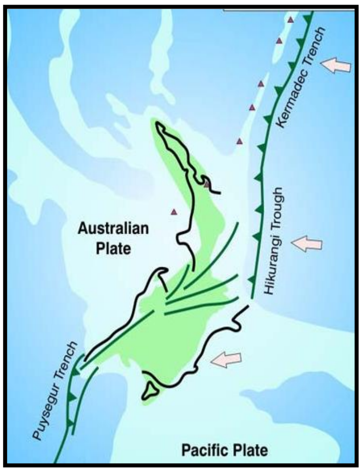
Approximately 250 million years ago, through the process of plate tectonics the ocean floor was pushed beneath the edge of the super-continent forcing the accumulated material to be scraped off the ocean floor and thrust upon the surface to form a region of steeply dipping, overlapping slabs (mountains) that stretched for several thousand kilometres along the Australian and Antarctic margin of Gondwanaland. During this time the rocks trapped at the base of the sediment piles underwent an intense transformation (metamorphism). Pressure and extreme heat were breaking down the sediment to form new metamorphosed rocks known as schist. This schist now forms the bedrock for the Queenstown Lakes District.

By the middle Cretaceous period about 100 million years ago, the patterns of circulation below the earth's crust were shifting and hot igneous rock began to well up beneath Gondwanaland forcing the land to split apart.



By 85 million years ago, the sea had flooded into this rift and New Zealand became an isolated, partly submerged drifting subcontinent about half the size of Australia. The new region of ocean separating New Zealand from Gondwanaland was to become known as the Tasman Sea. Thirty million years later the sea floor had stopped opening up.

Over the next 30 million years, the crust beneath New Zealand grew thinner, and as it did, the continent began to sink into the sea. It continued to sink lower and lower beneath the sea until about 25 million years ago when another shift in the tectonic plates caused the largely submerged continent to wrench apart. This rotating movement and intense pressure caused major cracks to develop in the rock. These cracks would eventually join to become New Zealand's great Alpine Fault.



(Source: McSaveney, 2005)

New Zealand now lay across two separate tectonic plates that were moving in opposite directions. As these plates rotated they continued to grind and collide into one another and eventually, as the colliding sections began to crumble, the land began to rise back above the surface of the sea. This brief but substantial period beneath the sea is marked by a layer of marine and estuarine deposits of sand, lime and mud.

Figure 2.5: Diagrams of the origin and evolution of New Zealand

Within the last 5 million years or so, much of New Zealand, including the Queenstown Lakes District has continued to experience uplift. Still occurring today, this uplift together with volcanic activity (in other regions of the country) is primarily responsible for the landscape that is seen today.

2.4.2 LOCAL GEOLOGY

The basement rock that underlies much the Queenstown Lakes District is called Otago schist (figure 2.6). The schist is a metamorphic rock that has formed from an original sequence of sedimentary rocks (sandstones and mudstones) and minor volcanic rocks. The metamorphism took place during the Rangitata Orogeny, a major phase of mountain building that affected the New Zealand region during the Jurassic and Cretaceous Periods between about 200 million and 70 million years ago. Parts of the original rock sequence can still be seen today towards the west of Lake Wakatipu and are known as Greywackes.

Derived from a Greek work meaning to split, schist is typically grey in colour with thin spaced laminations and many white quartz veins and bands. These thin spaced laminations are the reason behind why schist is so brittle and why it breaks apart so easily. Hence the primary cause of landslides in the region.

Figure 2.6: Photograph of Otago Schist

Schist rocks are the oldest in the area and have undergone many changes, such as folding and faulting. At one time (about 30 million years ago) the schist was partly beneath the sea and was overlain by marine sandstones, limestones and conglomerate. Much of these marine sediments have now been eroded away and are now only preserved in a few down faulted blocks associated with the northeast-southwest trending fault systems (the moonlight fault zone and Nevis-Cardrona fault system). Examples of marine remnants within the Queenstown Lakes District can be found at Bob's Cove and around Gibbston.

The mountainous areas in and around the district are also comprised of Otago schist and have been formed as a result of uplift (a mountain building period known as the Kaikoura Orogeny which is still occurring today) due to the compression of the earth's crust. This compression has caused folding and faulting within the earth's crust and is expressed at the ground surface as ranges (hills) and basins (valleys).

The range and basin landforms in the Queenstown Lakes District were developed through the growth of steeply dipping reverse faults during the last 2 million years. Many of these faults developed as normal faults more than 100 million years ago; however, they have reactivated as reverse faults because of the shift of the tectonic plates. One of these faults; the Moonlight Fault is an important geological feature that runs through the district. The fault separates two areas of basement rock; Otago Schist and Torlesse Greywackes. Further information of the local faults in the area can be found in the earthquakes section of this thesis.

The geological deposits within the first few tens of meters beneath the surface comprise of a variety of materials which reflect in composition to the older greywacke rocks. Including poorly consolidated sands and gravels laid down by rivers and streams, fine silty sediments which accumulated on the beds of ancient lakes (now drained or in-filled), massive sandy, muddy and gravely sediments deposited by ancient glaciers, as well as debris formed by landslide movement. Many of the surficial deposits are relatively young, and the processes that formed them are still occurring today. These processes are examined within the discipline of geomorphology.

2.5 GEOMORPHOLOGY AND LANDSCAPE DEVELOPMENT

Geomorphology is the study of landforms and the processes that shape them. This concept is important in order to understand the appearance and formation of the landscape, its history and dynamics and most importantly to predict future changes to the landscape. Knowledge of the surficial geology and geomorphology of a landscape is essential in assessing geological hazards. This knowledge can be subsequently used to minimise the potential problems that threaten land developments. There are three main geomorphological processes that have helped shape the Queenstown Lakes District.

- ***Glacial-morphology***

  From about two million years ago to about ten thousand years ago the entire district was at various times covered or partly covered by huge glaciers, which advanced then receded over about four separate intervals. This period of glaciation created an entirely new landscape; the gradual movement of ice carved out huge valleys for themselves and the material gouged out of the rock and transported by the glaciers have left a variety of deposits within the Wakatipu basin called moraines. After the glaciers retreated large lakes were left behind in the valleys that they had previously occupied.

  This period of glaciation dramatically changed the landscape and the hydrological characteristics of the district. For example geomorphological evidence suggests that Lake Wakatipu originally drained to the south, down the Mataura River. However due to the large quantities of moraine material that was left behind after the Dart glacier retreated, the lake was forced to carve out a new passage to the sea via the Kawarau Gorge and the Clutha River. The river channels south of Kingston are still preserved today but are now swamped filled.

  A natural consequence of glaciation is the fact that it has tended to over-steepen the valley walls promoting instability of the rock and although not directly responsible for the landslides and rockfalls that occur today, in some cases you could argue that it has a role to play. Landslides and rockfalls create a significant hazard to infrastructure in the Queenstown Lakes District particularly the roading network.

- ***Fluvial-morphology***

  Rivers and streams not only transport water but also transport sediment. The rate at which the sediment is transported depends on the quantity of material available and the flow rate of the river or stream. As the water flows across the landscape it adopts patterns depending on the regional topography and underlying geology, continuing to mobilise and release sediment, creating terraces and alluvial fans.

  Alluvial terraces and fans are typically derived of unconsolidated gravels, sand, and mud and typically infill most valleys and form many modern flood plains. In the Queenstown Lakes District these alluvial terraces and fans make up the majority of the low lying flat land and thus have been utilised extensively, creating a significant hazard to people and infrastructure. Hazards that arise from fluvial systems include flooding and liquefaction.

  The communities located around Lakes Wakatipu and Wanaka are predominantly at risk from these hazards. Kingston, Queenstown, Glenorchy and Wanaka are particularly vulnerable to inundation hazards from rising lake levels. Glenorchy is located in a complex hazard setting on the floodplain of the Dart and Rees rivers. It is also susceptible to debris flows from smaller tributaries east of the township. Parts of Queenstown, particularly the suburb of Frankton (where the airport is located) is vulnerable to liquefaction. Frankton is built on the alluvial fan created the Shotover River.

- ***Hillside-morphology***

  Earth materials can move downslope under the influence of gravity. Due to the brittle nature of the geology in the district, landslide occurrences are not uncommon and evidence of such movements are easily recognisable throughout much of the landscape. Earth materials that have moved downslope under the influence of gravity are primarily responsible for limiting the height of the mountain ranges in the district and filling in the adjacent valleys. This is clearly visible near the township of Makarora where frequent debris flows continually plague the area causing damage to infrastructure. Another area that is particularly vulnerable to the downslope movement of material is the Kawarau Gorge.

CHAPTER THREE
HAZARDS OVERVIEW

3.1 INTRODUCTION

The Queenstown Lakes District is vulnerable to a number of natural and technological hazards. These include earthquakes, mass movements, meteorological hazards, flooding, erosion, biological hazards, and technological hazards of which include transportation accidents, chemical exposure, infrastructure failure and terrorism. While all these hazards present a risk to the environment only some present a substantial risk to the lifelines assessed within this report. These Hazards have been summarised in the table below.

HAZARD	TYPE OF HAZARD
Earthquake	Alpine Fault Earthquake Local Fault Earthquake
Mass Movement	Rockfalls Landslides Debris Flows Avalanches
Meteorological	Heavy Rainfall Strong Winds Snowstorms
Flooding	Lake Flooding River and Stream Flooding Dam Failure Flooding Seiche Effects

Biological, technological and erosion hazards although important to acknowledge have not been dealt with in this project as they don't pose a great enough risk to lifelines. This thesis is primarily concerned with those hazards that pose an immediate threat to lifelines and have the potential to initiate a state of emergency if damaged.

Hazards that are discussed within this thesis may occur at any time and many of them are expected to occur within the next few years. For example, a large magnitude earthquake centred along the alpine fault is considered, by many scientists, to be already overdue. Flooding historically occurs every few years and mass movements occur annually. The Queenstown Lakes District is situated within a highly active environment and it would not be a surprise if one of these hazards were to occur tomorrow.

It is important to note that hazards do not always occur separately, many of the hazards particularly in the Queenstown Lakes District are all interconnected. Earthquakes and meteorological hazards can trigger mass movements. Meteorological hazards are generally the main cause flooding. Therefore, it is not uncommon to experience a meteorological hazard, a mass movement and inundation simultaneously.

The following chapter briefly discusses the hazards that present a substantial risk to lifelines in the Queenstown Lakes District. To ensure that hazards are fully understood and that this thesis remains appealing to the public a lot of background information has been included, most of this can be found in appendix A.

3.2 EARTHQUAKES

An earthquake is a sudden shaking within the earths crust caused by the release of accumulated strain. The Queenstown Lakes District, due to its proximity to the Alpine Fault and many other active faults in the Central Otago and Fiordland regions is at serious threat from a major earthquake. The effect of an earthquake on a community can range from being a minor disruption to a major catastrophe; however it is important to note that it is not actually earthquakes that kill. The natural killers are the landslides and tsunamis that may accompany earthquakes rather than the actual earthquake. Most deaths occur when buildings and other structures collapse from the shaking. As well as the damage caused from collapsed buildings, interrupted supplies of water, electricity and gas and broken sewage and communication systems, uncontrolled fires and blocked roads and bridges can tragically disrupt lives and communities.

3.2.1 TECTONIC SETTING

Earthquakes occur where land is under stress. In New Zealand the prime cause of such stress is due to the collision of the Pacific and Australian Plates (Cox et. al, 1999). The specific mechanism controlling this plate motion underneath New Zealand is complex. The mechanism is complex because the Australian and Pacific plates are grinding together in three distinct ways: To the east of the North Island the Pacific plate is being forced under the Australian plate, under the South Island the two plates push past each other sideways and to the south of New Zealand the Australian plate is being forced under the Pacific plate (Cox, 1999). This complex situation makes New Zealand one of the most geologically active countries in the world, and one where the consequences of plate tectonics are highly influential and unavoidable. Most of the geographic features that characterise New Zealand are direct results of this setting.

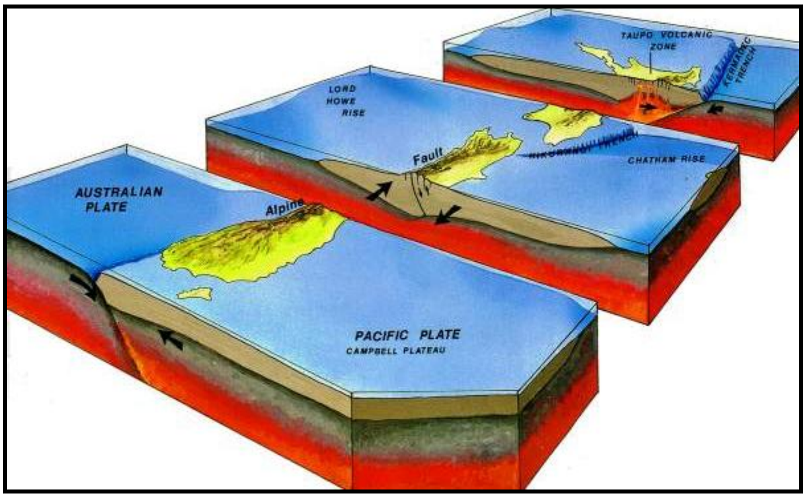


Figure 3.1: Cross-section of New Zealand illustrating movement of tectonic plates (Source: Cox, 1999)

Not only does stress build up within the plates, but also within the overlying crustal rocks causing them to fracture forming faults. Once a fracture has occurred the fault becomes a zone of weakness and thus prone to further movement in the future. The purpose of a fault is to take some of the strain away from the stress created at the subduction zone. The Queenstown Lakes District is vulnerable to earthquakes generated from two different sources. Earthquakes that are generated along the Alpine Fault and those earthquakes that are generated along local faults

3.2.2 ALPINE FAULT EARTHQUAKE

The Queenstown Lakes District sits directly upon a subduction zone where the Australian plate is grinding beneath the Pacific plate. The actual surface fracture of the Australian-Pacific plate boundary is marked by the 650km long Alpine Fault. Running from Blenheim at the top of the South Island to Milford Sound at the bottom of the South Island it is the largest fault in the country and can be compared with other great faults around the world such as the San Andreas Fault, in California. Deformation from this plate boundary movement extends back into the Pacific Plate and is responsible for the uplift of the Southern Alps.

Over the last 25 million years the Alpine Fault has taken up a good deal of the strain, by moving almost 500km horizontally, at an average rate of roughly 20m every thousand years. Each time the Alpine Fault has ruptured it has also moved vertically, lifting up the Southern Alps in the process. In the last 12 million years the Southern Alps have been uplifted by an incredible 20,000m and it is only the fast pace of erosion that has kept their highest point below 4000m.

Figure 3.4: New Zealand's Alpine Fault

In 1998, multidisciplinary research (Stirling et al., 1998) concluded that large quakes occur on the Alpine Fault every 100 to 300 years. Over the last 900 years the Alpine Fault has given rise to four earthquakes approaching magnitude 8 on the Richter scale. The two most recent earthquakes on the fault are both estimated at magnitude 8 occurring in 1720 AD and 1620 AD respectively. Two previous magnitude 8+ earthquakes on the Alpine Fault occurred about 1450 AD and 1100 AD. If this sequence continues, a large magnitude (8+) earthquake on the central part of the Alpine Fault is already due.

Plate boundary earthquakes particularly, those that occur at subduction zones, are characteristically very large and generally exceed the magnitude of any other earthquake. Furthermore, earthquakes from the central segment of the Alpine Fault are generally very shallow, mainly because there is no subducting plate to bend, creak or rupture at great depths. Shallow earthquakes typically have stronger shaking intensities than earthquakes of the same magnitude that occur deeper within the earth's crust. Therefore more damage can be expected from a shallow earthquake than a deeper earthquake.

If faulting was to occur along the central part of the Alpine Fault such an effect would be felt throughout the entire South Island and will be stronger and longer lasting than any jolts ever recorded in the area. When the next 'big one' happens, it will be frightingly recognisable by a minute or more of shaking. It is calculated that a severe Alpine Fault earthquake will awaken sleepers, dislodge ornaments and crack windows in North Island areas hundreds of kilometres away.

3.2.3 LOCAL FAULT EARTHQUAKE

Earthquakes that occur along faults in and around the Queenstown Lakes District are called local fault earthquakes. Local fault earthquakes tend to be more localised than plate boundary earthquakes and generally originate at much shallower depths. In contrast with the 650km Alpine Fault; these local faults tend to be only about 50 km long and their average rates of movement, calculated from field observations are less than 1mm per year (Turnbull, 2000). The purpose of these local faults is to take some of the strain away from the Alpine Fault and the stress created by the subduction zone.

Although these faults are smaller than the Alpine Fault their strength should not be underestimated. For example, many of these faults have been assessed in terms of the 'maximum credible earthquake' likely to be generated along them and three fault systems in particular have the potential to generate earthquakes greater than magnitude 8 on the Richter scale (Turnbull, 2000). These faults are called the Hollyford Fault System, Moonlight Fault System and the Nevis-Cardrona Fault System (figure 13).

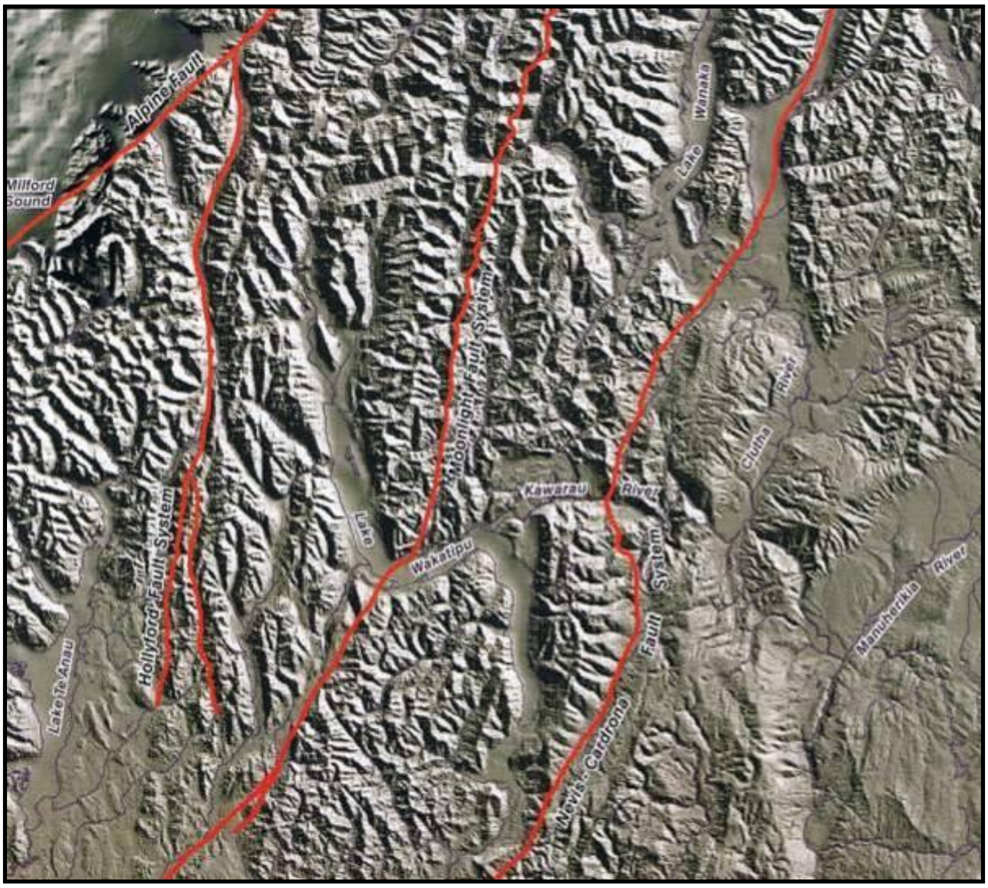


Figure 3.4: Shaded topographic relief model of the Queenstown Lakes District illustrating major fault systems. (Source: Turnbull, 2000).

The Moonlight Fault which is a major fault system that transverses the area can be traced from the south coast of Fiordland, northeast through Lake Wakatipu to the vicinity of Haast Pass. Available evidence shows that the Moonlight Fault has moved only once, probably sometime within the last 8000 years and caused a vertical displacement of about 2 meters and a horizontal displacement of 0.5 meters (Mapped near Mount Nicholas Station on the south side of Lake Wakatipu). The resulting earthquake is estimated to have had a local felt intensity of around VII on the Modified Mercalli Scale (For comparison, the Edgecumbe earthquake 1987 had a similar intensity) (Turnbull, 2000). The Nevis-Cardrona Fault System extends from outside the district along the Nevis River, through the Cardrona valley underneath the Wanaka/Hawea basin to join the Hawea fault north of the southern end of Lake Hawea.

Other probable local faults that are capable of generating an earthquake powerful enough to shake the Queenstown Lakes District include, but are not limited to:

- The Grandview fault which is located outside the district and runs along the east side of the Hawea valley.
- The Pisa, Lindis, Dunstan and Ranfurly faults in Central Otago are roughly parallel and all have significant fault traces that have been active in the last 500,000 years.
- The Ostler Fault in the Mackenzie Basin near Lake Ohau has a 100m high fault scarp and is more than 50 km long. It was active 3500 years ago and it has the potential to move in 2m jumps.
- The Hawea Fault zone extends along the line of Lake Hawea and up through the Hunter Valley in a north nor-easterly direction.
- The Larkins and the Shotover faults have similar trends to the pre-mentioned faults and although there are no documented displacements of Quarternary surfaces, these faults are considered to be potentially active.

In addition to the Alpine Fault and the several other local faults in the Otago region, earthquakes may also be created off the south-western coast of the South Island, next to scenic Fiordland. This southernmost coastal region has numerous major fault traces that have had various histories since about 50 million years ago, but few have been active in the last 2 million years. Yet many seismologists believe that the Queenstown Lakes District is much more likely to be shaken up by seismic activity off the coast of Fiordland due to its proximity to the plate boundary than by quakes on a local fault (GNS, 2007).

3.2.4 EARTHQUAKE HAZARDS

The energy released by the planet during an earthquake is so intense that it commonly creates another entire range of hazards that can have both local and widespread impacts. Hazards that are associated with earthquakes include ground shaking, fault rupture, liquefaction, mass movements and seiche phenomena, as well as secondary effects such as structural damage to buildings, roads and bridges, urban fires and human effects. Hazards may vary slightly throughout the district, not only because of the magnitude, location and depth of an earthquake, but also because of the geology and geomorphology of the area.

- ***Ground Shaking***

  Ground shaking is the main cause of earthquake damage and can last from several seconds to a couple of minutes. The severity of the ground shaking at a particular point depends on a combination of factors including the magnitude of the earthquake, the distance from the earthquake epicentre and the local geology. Soft ground, such as sandy or silty sediments, tends to amplify ground shaking more than the likes of bedrock. Ground shaking tends to cause damage to buildings or other rigid structures as well as causing unsecured items, such as ornaments, to fall over.

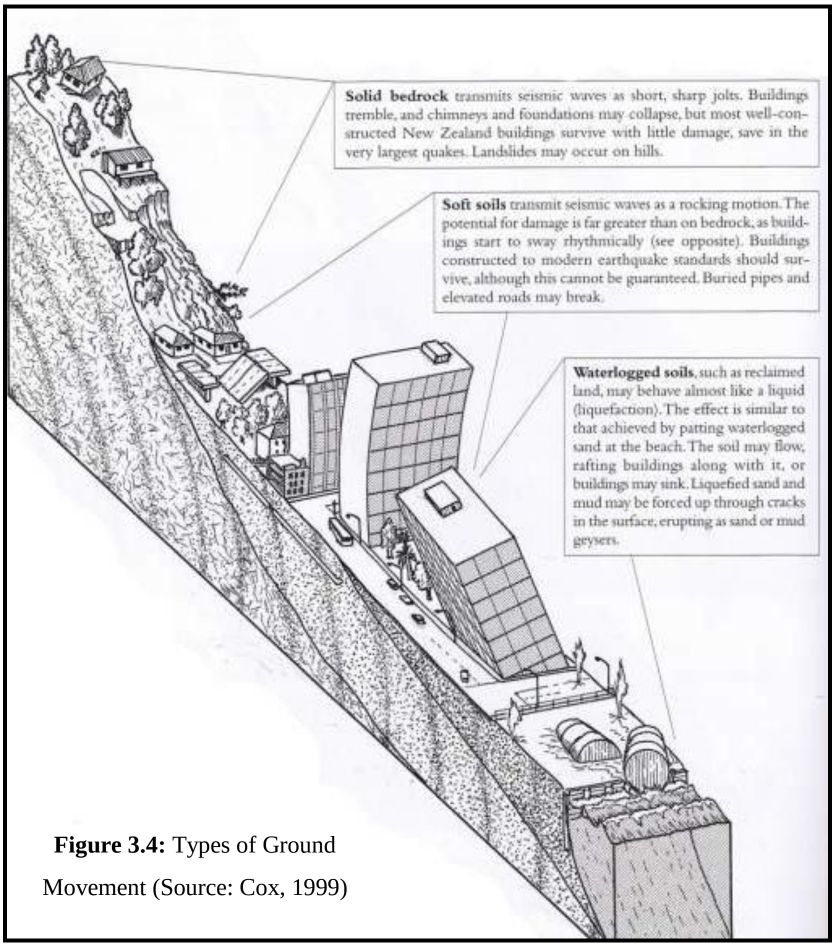


Figure 3.4: Types of Ground Movement (Source: Cox, 1999)

Aftershocks will also occur after large earthquakes as the land adjusts to the displacement that has occurred. These smaller earthquakes can occur in the first few hours after an earthquake and can continue for weeks, months, or even years after a large quake. After shocks are quite serious effects as they tend to cause further damage to already weakened buildings. It is also important to be aware of the fact that some earthquakes are actually foreshocks and that a larger earthquake may still occur. Unfortunately we are currently unable to determine whether an earthquake is a foreshock or whether it is the main event, until after the episode.

Ground shaking during an earthquake is seldom the direct cause of death or injury. Most injuries result from collapsing structures such as walls; flying glass or debris; falling objects or when people try to move more than a few feet during an earthquake.

Ground shaking from a major earthquake will be felt throughout the entire district and the magnitude will be relatively consistent. However, there may be some places where the magnitude may be slightly amplified (refer to map one). These places include areas situated on alluvial fans (e.g. Frankton) or on the valley floor (e.g. Wanaka CBD). Also the location of the earthquake epicentre will cause a difference in the felt intensity. For example, an earthquake located along the Alpine Fault will be felt more in the north of the district than in the south.

- ***Fault Rupture***

If an earthquake is large and shallow (generally greater than magnitude 6.5 and less than 40km deep) the displacement on the fault may reach the ground surface, offsetting the ground both horizontally and vertically. If fault rupture occurs, anything that crosses the fault such as underground services (water pipes) or surface structures (buildings, bridges) will be severely damaged or destroyed. Fortunately the fault rupture hazard is generally confined to a relatively narrow strip along the fault and because fault rupture tends to occur repeatedly in the same place the location of future ground movement can be predicted with some certainty.

Figure 3.5: Effect of Fault Rupture

Fault rupture generally creates permanent features in the landscape such as surface ruptures or scarps, displacement of river channels or other topographic features, offsets of fences and roads and twisted railways (figure 3.5). In the Queenstown Lakes District there are a number of faults that transverse the region and many of them have fault scarps. Fortunately the locations of most of these faults are a distance from any dense urban areas and hence the damage expected from fault rupture will be limited to the roading network (refer to map one).

- ***Liquefaction***

  Liquefaction occurs when saturated fine grained sediments such as sand and silt behave more like water than rock during an earthquake (figure 3.4). During intense ground shaking (greater than MM intensity 6) these sediments can lose there strength entirely causing rigid structures such as buildings or bridges, to tilt or sink into the liquefied deposits. Underground services such as water pipes can become buoyant and rise to the surface and unsupported land such as river banks and wharves can spread sideways.

  Based on the effects of the 1988 Te Anau earthquake (Turnbull et al. 2006) it is likely that the next major earthquake to affect the Queenstown Lakes District will cause widespread liquefaction and partial collapse of some lake-edge deltas; where structures such as wharves, houses and airstrips have Glenorchy, Frankton and parts of the Kelvin Heights Peninsula (refer to map two).

- ***Landslides***

  Severe ground shaking during earthquakes is also very effective at destabilizing slopes and triggering landslides particularly when coupled with high groundwater content following high intensity rainfalls. Mass movements as a result of seismic shaking are unfortunately very difficult to predict however, due to the highly fractured and volatile rock that underlies much of the district it is expected that there will be numerous landslide occurrences ranging from small rockfalls that may block roads for a couple of hours to massive deep seated landslides that may take weeks to clear.

  After a major earthquake it is likely that the road leading into the district through the Kawarau Gorge will be completely blocked from at least one or more rockfalls. Mass movements are also likely to block many of the other roads in and around the district completely disrupting road transportation for weeks after the event. Fortunately most of the known landslide prone areas (refer to map seven), are distanced away from developments however it is not completely unconceivable that a landslide may occur in a densely developed area, such as reactivation of the Queenstown Hill Landslide which is likely to destroy many houses and will most likely result in fatalities.

- ***Seiches***

  A seiche is a standing wave that develops within an enclosed body of water that has been disturbed by seismic movement. Caused by the rocking movement of the earth's surface, lakes generally start to oscillate back and forth like water in a bath tub. The frequency of the oscillation is determined by the size of the lake (its depth and contours) and temperature. Lake Wakatipu already exhibits seiche like effects as it rises and falls daily. However, these effects are thought to be due to underwater currents and only cause the lake to rise and fall a couple of centimetres. An earthquake generated seiche will effectively raise the water level of the lake a couple of meters causing devastating effects to lake side communities. In New Zealand during the 1929 Buller earthquake a seiche was reported at Lake Rotoroa where the lake water withdrew to expose 50m of lakebed, before rising to flood the surrounding shoreline. All the lakes within the Queenstown Lakes District are capable of producing seiches.

Figure 3.6: Example of earthquake generated waves reaching a shoreline.

If a large landslide fell into a lake, a large wave could be generated. An example occurred during the 2003 Fiordland earthquake. A rock fall into Charles Sound created a wave that travelled 800m across the sound and damaged vegetation up to 4 – 5 m above high tide level, with trees debarked and rock stripped of vegetation. (Hancox et al, 2003). An event of this type could easily occur on Lakes Wakatipu, Wanaka and Hawea with high steep hillsides rising directly from the lake.

A third possible cause of waves in lakes is from submarine slides of sediment deposited in the deltas of inflowing rivers. Such slides can generate large waves, and have been recorded historically within lake settings in the world. In 1937 an earthquake triggered a slump on the Dart-Rees delta at the head of Lake Wakatipu, although apparently without large wave generation (Brodie and Irwin 1970).

The effects of a seiche can range from unnoticeable to devastating and depending on the size of the movement may range from a couple of centimetres to meters high. Following an earthquake people within lake side communities should avoid the lakes and move to higher ground.

- ***Fire***

  In urban centres, one of the most destructive consequences of a major urban earthquake is the fire that follows. Fires can be generated due to broken electrical power and gas lines. In the event of water mains rupturing and a loss of pressure, it may also become difficult to stop the spread of a fire once it has started. Although occurrences of fires after an earthquake are difficult to predict it is likely that fires will be ignited in Queenstown and Wanaka.

- ***Human Impacts***

  Earthquakes not only greatly affect the built environment but can also have devastating human impact. During an earthquake some people may experience nausea and some may also start to panic. This can lead to more long term psychological effects such as post traumatic stress disorder, where people can suffer from depression and other ailments (e.g. people may live in fear and/or have trouble sleeping especially children). Other impacts include disease due to the lack of basic necessities, loss of life, higher insurance premiums, general property damage, road and bridge damage, and collapse of buildings or destabilization of the base of buildings which may lead to collapse in future earthquakes.

3.2.5 EMERGENCY MANAGEMENT IMPLICATIONS

Earthquakes occur with little or no warning and have the ability to cause widespread damage not just within the Queenstown Lakes District but throughout neighbouring districts. This places additional pressure on the availability of resources and personnel within the district, as well as from outside it. A large magnitude earthquake is likely to damage multiple lifelines simultaneously.

The impact that the earthquake will have, will be very much dependent on a number of factors such as where the earthquake is located and when the earthquake occurs. For example during the day many people will be spread throughout the district resulting in a more diverse response. At night many people are located within towns meaning that emergency response will be concentrated in urban areas. If the earthquake occurs in winter there are a number of other implications to consider such as large numbers of people trapped on ski-fields and the effect of snow/ice hindering emergency response.

Earthquakes generate a number of secondary hazards that generally cause more damage than the earthquake itself. Unfortunately the effects of these hazards are very unpredictable and emergency management agencies will be required to assess there responses after the event has occurred. In spite of this, general responses can still be determined using scenario-based planning.

3.3 MASS MOVEMENTS

Mass movement is the down slope movement of earth surface materials, snow or ice under the influence of gravity. Mass movements can vary in size from a single boulder, that only cause minor disturbances, to movements that involve huge volumes of material that can cover many kilometres causing extensive damage to anything in its path. Mass movements generally occur naturally after heavy rain or earthquakes but they can also occur for no particular reason.

They can be caused or made worse by human activity such as vegetation removal; creating unsupported slopes such as roadside cuttings; other excavation; or, increased soil moisture (from leaking water pipes etc). Downslope movement can cause enormous damage to infrastructure and properties and generally occur with little or no warning. Roads, homes, bridges, dams, airports and recreational areas can be destroyed, and at times cause injury and loss of life. Utilities such as pipelines, electrical wires, and communication towers can be damaged. No building regardless of its structural configuration, can withstand the effects of downslope land movement.

3.3.1 TERMINOLOGY

Major mass movements are unpredictable, but will occur in the future, probably initiated by displacements on the Alpine Fault. Mass movements can be divided into different types depending largely on the manner and speed in which material moves down the slope. The types of movements include slides, falls, slips, topples, flows, creep or avalanches. Some mass movements can exhibit a combination of these characteristics. The material involved is also another criteria that is used to classify movements and the combination of the type of movement and material involved gives a basic description of the mass movement (e.g. rock fall, debris flow etc). In the Queenstown Lakes District mass movements can be categorised into one of four types of movements. These include rockfalls, landslides, avalanches and debris flows.

3.3.2 ROCKFALLS

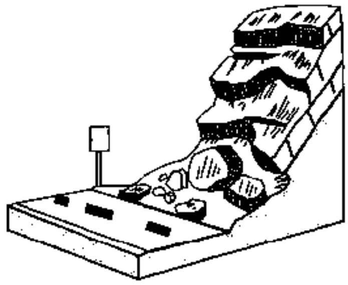


Figure 3.7: Rockfalls

A rock fall is a fragment or fragments of rock that are detached from a vertical or sub-vertical cliff face by sliding, toppling, or falling, it then proceeds down slope by bouncing and flying along ballistic trajectories or by rolling on talus or debris slopes (figure 3.7). Rockfalls have extremely rapid velocities ranging from 3 to 100 meters per second. Rockfalls can happen without warning and have devastating consequences, although they don't pose quite the same amount of risk as a large scale slope failure. However rockfalls can still close major transportation routes for days at a time and history tells us that they kill the same number of people. Rockfalls are generally triggered by either a climatic, biological or tectonic event that causes a change in the forces that are acting on the rock. Areas where rock falls occur are generally characterised where the bedrock is exposed to the environment. In many areas in the Queenstown Lakes District rockfall prone areas have been marked with signs. Rockfalls are frequent within the Kawarau Gorge (refer to map 3).

3.3.3 LANDSLIDES

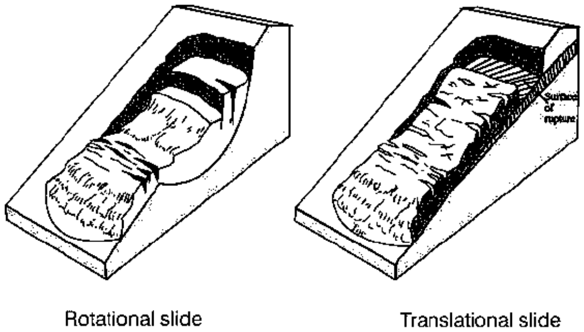


Figure 3.8: Types of Landslides

A landslide is the downslope movement of material under the influence of gravity. Landslides can consist of both surficial material and bedrock particularly in the Queenstown Lakes District where the bedrock material is highly volatile and brittle. Landslides can be characterised into two types of movements, rotational and translational (figure 3.8). Rotational landslides are characterised by a curved rupture surface where the movement is rotational about an axis. A landslide in which the mass of soil and rock moves out or down with little rotational movement is called a translational slide. Landslides are typically triggered by heavy rain or excess water saturating the soil overlying the slope.

3.3.4 AVALANCHES

An avalanche is a mixture of snow, ice, soil, rock and boulders that moves downslope at terrifying speed, annihilating everything in its path. It can generate a strong accompanying wind that can tear trees from their roots. Avalanches require a combination of steep slopes and a heavy snowfall (figure 3.9). A common trigger is the deposition of wet snow over ice or a hard crust, with failure occurring at the base of the snow. Avalanches may also be triggered when the underlying material supporting the massive snow cover can give way because it has been soaked by spring rains or destabilised by alternating periods of precipitation and warm, dry winds flowing down the leeward side of the slope. Sometimes a slope is so unstable that thunder or even a loud shout is sufficient to trigger sliding of the overloaded snow. An avalanche can travel at speeds ranging from 40 to 300km/hr depending on the angle of the slope, the density of the snow mixture and the length of its path. Snow Avalanches generally only pose a threat to ski-fields in the district such as the Remarkables ski field and Cardrona Ski field.

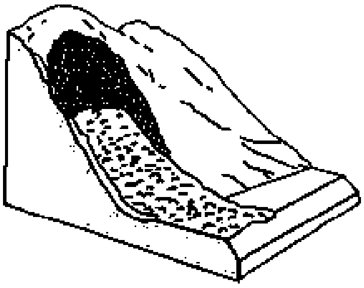


Figure 3.9: Avalanches

3.3.5 DEBRIS FLOWS

Debris flows generally start on steep slopes however; once they get started they can travel over gentle slopes. The most hazardous areas are at the bottom of valleys and slopes excavated for buildings and roads. Debris flows also referred to as mudslides or mudflows typically occur during or following intense rainfall on water saturated soil. They usually start on steep hillsides as soil slumps or slides that liquefy and accelerate to high speeds. Multiple debris flows that start high in canyons commonly funnel into channels. There, they merge, gain volume and travel long distance from their source. Debris flows commonly begin in depressions at the top of small gullies on steep slopes, making areas down slope very hazardous.

Road cuts and other altered or excavated areas of slopes are particularly susceptible to debris flows. These and other landslides onto roadways are common during rainstorms, and often occur during milder rainfall conditions than those needed for debris flows on natural slopes. Areas where surface runoff is channelled such as along roadways and below culverts, are common sites for the formation of debris flows and other landslides. Not surprisingly, water plays a

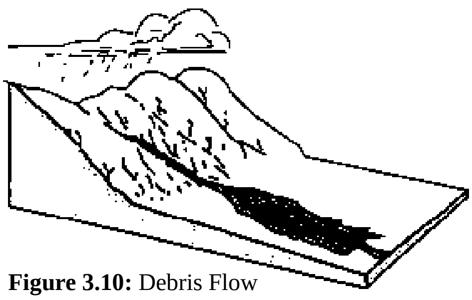


Figure 3.10: Debris Flow

major role in mudflow and debris flow formation and transport. These flows occur on slopes where heavily water saturated soils lubricate inicipate basal failure planes, decreasing their shear resistance to movement and facilitating downward flow. The rate of downslope movement can be as rapid as 3m/s or slow as 0.6m/yr. Many of the catchments in the Queenstown Lakes District are vulnerable to debris flows as most of them are short and steep making them great mediums for transport. The eastern side of the Makarora valley is particularly vulnerable to debris flows.

3.3.6 EMERGENCY MANAGEMENT IMPLICATIONS

Mass movements may occur with or without warning. Generally, if there is evidence that a mass movement is likely then the council would implement measures to either stabilise the slope or implement measures to reduce that hazard (e.g. evacuation of residents). Mass movements are generally restricted to a defined area and thus can be managed more effectively than other hazards considered within this report. Although the location of the next mass movement may be unpredictable the general responses used to manage a mass movement can still be prepared. The weather has a substantial influence on the speed of responses as it has the potential to trigger further movements and is generally used to assess slope stability.

3.4 METEOROLOGICAL

Meteorological disasters are extreme weather events that can wreak havoc on communities by destroying property, leaving injury and even death in their wake. Meteorological events by their very nature affect the whole of the region simultaneously and will disrupt many lifelines, including main access roads, the rail link, the airport, electricity supplies and communication. Meteorological disasters are among the most frequent hazard threatening the district. The meteorological hazards that particularly affect the Queenstown Lakes District include heavy rainfalls, strong winds, and snowstorms. Most of the time weather seems to be subtle and follows periodic trends that cause no real risk to people and infrastructure. However occasionally extreme weather phenomena do arise and present a serious threat to lifelines.

3.4.1 STRONG WINDS

The prevailing airflow over the Queenstown Lakes District at about 18,000ft well above the mountain tops is westerly in all seasons except spring when the direction becomes more west-northwest. At ground level the winds are frequently funnelled through mountain valleys and gorges which cause the direction to be more northerly. The average wind speed tends to be strongest in summer (50-60kph) and weakest in winter (30-35kph) (NIWA, 2001).

Strong winds in the Queenstown Lakes District are characterised by weather patterns where an incoming low pressure system from the southwest is blocked by a high pressure weather system situated to the east of the South Island. The convergence of these two systems tightens up the isobars over the region causing high winds to blow initially from the northwest and then latterly from the southwest as the associated weather system passes over the area. Strong winds in the Queenstown Lakes District can be heavily influenced by the local topography.

Strong winds may have very severe consequences that may lead to the loss of lives and injuries; these include devastation to forests, destruction of essential infrastructure and damage to buildings. While it is often thought that wind damage is caused by uniform horizontal pressures, it is mostly caused by vertical uplift, suction and torsional forces. Strength of wind generally increases with altitude.

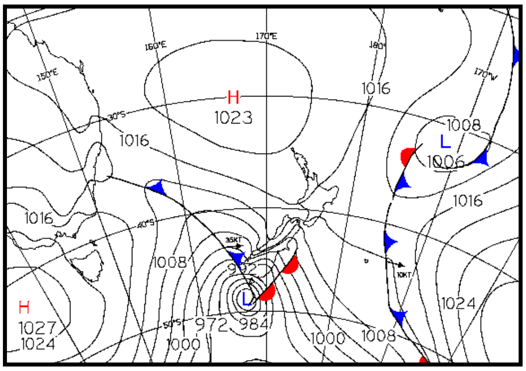


Figure 5.4: Effects of the 1999 flooding event after sewage was released into the lakes.

- ***North-West Winds***

  The northwesterly wind in the South Island is also known as a föhn wind. A föhn wind occurs when warm moist air from over the Tasman Sea is pushed up by the presence of the Southern Alps. As the wind moves upslope, it expands and cools, causing rain to fall on the west coast. As this dehydrated air then passes over the crest it begins to move downslope. As the wind descends to lower levels on the leeward side of the mountains, the air temperature increases adiabatically as it comes under greater atmospheric pressure creating strong, gusty, warm and dry winds.

  Nor' westerly winds can reach mean wind speeds above 50 knots (93km/h). If extreme turbulence occurs in the lee of the mountains, gusts may exceed 80 knots (148km/h). Wind speed tends to rise and may reach storm force, until the passage of a cold front across the district brings rain or snow, and the direction shifts to the south-west. Wind speeds then slacken, but can remain strong. Such windstorms can last for 6-12 hours (NIWA, 2001).

- ***Southerly Gusts***

  Extreme wind gusts of up to 80 knots can occur when there is a sudden change in wind direction generally to a southerly direction. They tend to be of short duration, lasting less than one hour, but a sudden blustery onset can cause damage to loose roofing, fences, signs and power lines and can blow down trees.

3.4.2 HEAVY RAIN

The distribution of rainfall in the Queenstown Lakes District is primarily controlled by the topography. The Queenstown Lakes District is relatively sheltered from heavy rainfalls due to the shielding effect of the Southern Alps. However, if the fronts are unusually vigorous, move slowly or stall over the district then people are seriously at threat from heavy rain, particularly where the mountains are exposed to the direct sweep of the westerly and northwesterly winds.

Climate scientists define heavy rainfall as more than 100 mm of rain falling in a day (Met Service, 2007). The irregular topography of the Queenstown Lakes District, with its many mountain ranges, is responsible for the great variations in rainfall patterns. Generally, because of the lie of the southern alps, the Queenstown Lakes District is relatively sheltered from heavy rainfalls however if the fronts move slowly enough or stall above the district then people are seriously at threat from heavy rain. Heavy rain often falls in the district when a depression crosses the South Island or becomes slow moving towards the east. Another situation which brings heavy rain is that of a cold front orientated in a north south direction moving slowly eastwards across the region.

Under certain conditions, the intensity and duration of the rainfall can increase with elevation as the cloudy air is forced over the terrain. So when heavy rainfalls are being recorded at the feet of mountain ranges, it is often raining twice as much near the crests. Many of streams and rivers in the district can hence show a runoff response to heavy rainfall about four hours after the event. Therefore, timely warnings are critical as lots of water in the district can lead to flooding and widespread landslides which may intensify the damage to properties and may put lives at risk (figure 3.12).

Figure 3.12: Surface flooding caused by heavy rain and exacerbated by impervious surfaces.

3.4.3 SNOWSTORMS

In New Zealand a heavy snowfall is said to occur when 25cm or more of snow falls in a day or when 10 cm of snow falls in six hours (Met Service, 2007). Snowfalls in the Queenstown Lakes District occurs frequently and for many people in the district the occurrence of heavy snowfall is likely to be seen as a blessing rather than a hazard. However, the effect of heavy snowfalls on lifelines in the district could be disastrous especially it the snowstorm lasts longer than a week.

In the valleys and basins of the district snow falls on average on five to ten days per year. In winter, mountains above about 4000ft will have snow lying for periods of a month or more and a considerable portion of the high ground will also be covered with snow in winter.

Large snowstorms are typically the result of slow moving deep depressions embedded in a cold south-westerly or south-easterly air-stream. The pressure at the centre of these depressions can sometimes rapidly fall, forming what is termed a "bomb" depression. This can lead too much enhanced precipitation, especially if the storm stalls over an area for more than 24 hours. Snowstorms can occur as early as June and as late as November. Snow can often be observed at ground temperatures up to 5°C.

Heavy snowfall events generally start off as light rain and then gradually change to moderate or heavy snow. This is because the snow falling from above melts and forms rain droplets before it reaches the ground. However, in doing so, heat from the air is taken away, cooling the air, eventually allowing the snow to fall to lower elevations (De Lisle, 1968).

Figure 3.13: Heavy snowfall closes roads

Heavy snowfalls have been known to cause roofs to collapse because of the weight of the snow. Transportation networks are commonly impacted due to snow. As little as 4cm of fresh snow on New Zealand Roads can cause disruption to travel and road closures. Because of the mountainous terrain in the district road access in and out of the district will be very difficult (figure 3.13). The airport will be forced to close and emergency services will struggle to reach critical locations. A heavy fall of snow can disrupt all types of communications and cut power due to the widespread damage that will be sustained by the power lines due to strong winds, heavy snow loads or debris falling across lines. The rural community is particularly affected by stock losses causing long-term business interruption.

3.4.4 EMERGENCY MANAGEMENT IMPLICATIONS

Meteorological hazards generally occur with advance warning from the New Zealand Meteorological Service. The consequences of meteorological hazards are not as severe as earthquake hazards however they still affect the district as a whole. Meteorological hazards rarely present a risk to human life and only affect those lifelines situated in exposed areas. Meteorological hazards have the potential to hinder post disaster recovery as most roads are likely to be blocked by fallen trees, branches and other debris. It would be wise for emergency agencies responding to a meteorological disaster to carry chainsaws and other light equipment to ensure rapid responses. Emergency response in the event of a meteorological hazard can only begin once the initial event has dissipated.

3.5 FLOODING

Flooding in the district is primarily caused by the weather; however floods can also result from a number of other causes. Weather related flooding can be categorised into lake flooding, which occurs when the water levels in the glacier lakes rise above naturally allowable levels, or river flooding which occurs when the local tributaries that flow through communities into these glacier lakes overtop there banks. Localised surface flooding may also occur in some areas where the stormwater system is unable to cope with the increased rainfall. Other types of flooding that are not caused by the weather include tsunami, dam failure and pipeline failure. Flooding presents a real concern for the residential and commercial development that surrounds these natural waterways.

3.5.1 LAKE FLOODING

The main type and most catastrophic form of flooding in the Queenstown Lakes District occurs when the lake levels rise above their maximum and overflow into the streets of neighbouring communities. The main cause of high lake levels is the natural imbalance between the capacity of water flowing into the lakes compared with the magnitude of water flowing out of the lakes. Currently, there is almost five times the water flowing into the lakes, as there is flowing out. There are several glacial lakes in the Queenstown Lakes District and most of them are prone to flooding however, currently only two of them present a substantial risk to lifelines.

- ***Lake Wakatipu***

  Lake Wakatipu occupies a long u shaped valley which has been scoured out by the action of glaciers. The general topography can be described as a reversed "N" shape (Peat et. al., 1999). The Dart and the Rees rivers fed into the lake at the head. At the foot of the lake is a natural dam of moraine left by the glacier which formerly occupied the lake basin. In the geological past the lake was drained from its foot by a river which flowed out to join the Mataura system. Now it is drained by the Kawarau River which flows generally eastward from Frankton Arm via the Gibbston Basin to join the Clutha River at Cromwell.

Figure 3.14: 1999 Flooding of Lake Wakatipu

Lake Wakatipu has a long history of flooding, during the last 50 years there have been eight episodes where the level of the lake has been high enough to flood the communities situated along the lake edge. The most recent episode and the most significant was in the year 1999 when Lake Wakatipu rose to a record level of 312.78m above sea level, approximately 1.2m above the height of the steamer wharf deck in Queenstown (figure 3.14). The damage was extensive, causing the closure of numerous businesses for up to 3 weeks at an estimated total cost of $56 million. Other notable events include the flood of 1924, which was important due to the compounding effect of high wind and waves, and floods in 1994 and 1995, when two relatively large flood events occurred in successive years (Forsyth, 2004).

The Shotover River and its delta, influence the duration and level of flooding in Lake Wakatipu through the transport of both water and sediment to the Kawarau River. The Shotover River, due to the highly erodible nature of the catchment, carries with it huge volumes of sediment which is deposited at the confluence of the Shotover and Kawarau Rivers approximately 3.5 km downstream of the Lake Wakatipu and the Kawarau Falls Bridge. This deposited sediment reduces the cross sectional area of the channel and raises the bed level, decreasing the rivers capacity (figure 3.15). As the Kawarau River is Lake Wakatipu’s sole outlet the risk of flooding is significantly increased, until the high flows in the Shotover River recede (QLDC, 2006).

Figure 3.15: Shotover River delta with the Kawarau River in the foreground, flowing left to right

The normal level of Lake Wakatipu generally lies close to 310m above sea level (ORC, 2007). Unfortunately the exact level of the lake is unknown due to the unique and mysterious rhythmic rise and fall in water level. The variation is about 12cm every five minutes at Bob’s Cove, the best place to observe it. Scientists are still puzzled by the phenomenon but believe it may be linked to currents flowing through subterranean passages (Davie Lovell-Smith and Partners, 1993). The level at which communities begin to become inundated ranges from 311.25m to 312m, at this level the lake begins to flood into the streets of the Queenstown CBD through the stormwater system (QLDC, 2007) (refer to map 4).

Queenstown is not the only community that is affected by the high lakes levels of Wakatipu. The township of Glenorchy located at the northern tip of the lake is also situated close to the shore line. Furthermore, the road to Glenorchy that runs along the edge of Lake Wakatipu is susceptible to slippages and washout during severe weather events potentially resulting in a loss of access and consequently, isolation for not only Glenorchy but also for the outlying communities of Kinloch and Paradise (refer to map 6)

Kingston is a small, primarily residential settlement located at the southern tip of Lake Wakatipu. With its large lakefront reserve area and generous set back Kingston properties have a reduced risk compared to the likes of Queenstown and Glenorchy but there is still a risk as proved by the flood of 1999 which still inundated 30 homes and damaged a local tavern, railway station and washed out parts of the railway track (Becker et. al., 2000) Along with the rest of the district Kingston is also facing strong development pressure. Therefore it is essential that we take the opportunity to ensure flood risk is mitigated through flood sensitive design and appropriate land use, especially with the imminent threat of climate change.

- ***Lake Wanaka***

  Lake Wanaka is New Zealand's fourth largest lake. It is fed by the Matukituki and Makarora Rivers, and is the source of the countries largest river, the Clutha. The only flat land around the lake is located at the southern end, surrounding the outflow to the Clutha River. This is also the site of the towns of Wanaka and Albert town; creating a significant flooding risk.

While the outlet of Lake Wanaka does not have the same capacity issues as Lake Wakatipu, there is still a considerable risk to the township of Wanaka and the lower parts of Albert Town (refer to map 5).

Figure 3.16: 1999 Flooding of Lake Wanaka

Wanaka has a similar history of flooding as Queenstown. The most significant flooding event was in 1878, when the lake rose to a record level of 281.8m, 1.8m above the level of Ardmore Road. The flood of 1999 was the second highest in 122 years of record and reached a peak height of 281.3m, causing the inundation of numerous CBD businesses. Like Queenstown flood damage in Wanaka can be exacerbated by exposure to wind-generated waves and transported debris (Forsyth, 2004).

3.5.2 RIVER AND STREAM FLOODING

Western catchments lying close to the main divide include the Rees and Dart (tributaries of Lake Wakatipu), the Matukituki and Makarora (Lake Wanaka), and the Hunter (Lake Hawea). The Kawarau and upper Clutha River combine to drain water from these lakes towards the coast. Two main tributaries, the Shotover and Arrow Rivers, join the Kawarau River in the Wakatipu basin. Flooding in these rivers is likely to be caused by heavy rain over the northwest side of the main divide, and is often accentuated by springtime snow melt.

- ***Queenstown***

The township of Queenstown is exposed to flooding from small tributaries that drain into Lake Wakatipu. Horne Creek is a relatively small source of Lake Wakatipu that carries most of the stormwater flows from the urban Queenstown catchment. The Queenstown Central Business District has developed around and over this waterway causing the channel to be highly constrained. There is a risk of channel blockage during floods due to woody debris sourced from the steep, heavily wooded catchment, the relatively small waterway area and numerous culvert and bridge crossings that act as potential hydraulic restrictions. High flooding events are likely to flow along streets damaging property and posing a danger to pedestrians. Horne Creek (figure 3.17) has a small, steep catchment and unlike the situation with lake flooding, flood warning is not a practical or reliable method of managing the hazard. Existing measures to manage flood hazard associated with Horne Creek include a detention dam and debris trap at the confluence with Brewery Creek and the utilization of the sports ground as a detention area.

Figure 3.17: Flooding of Horne Creek, November, 1999

- ***Wanaka***

Some developments in Wanaka are also exposed to the additional hazard from the overtopping of Bullock Creek. Bullock Creek is a small tributary that forms the primary conveyance of stormwater from the eastern urban catchment. Bullock Creek is sourced from a natural spring; the channel is largely open and unconstrained thus increasing the risk of flooding.

If high flow out of Lake Wanaka coincides with high flows from the Hawea River the lower parts of Albert Town could be at greater risk from flooding. Contact Energy Ltd who operate the detention dam at the outlet at Lake Hawea have said that they will do their best to hold

Figure 3.19: Lake Hawea Detention Dam

discharges from Lake Hawea during flood events but if storage is inadequate to safely retain flood inflow they will have no choice but to release water in accord with dam safety protocols.

- ***Glenorchy***

  The township of Glenorchy and its environs is located in a complex hazard setting, being exposed not only to inundation from high lake levels but also water and debris flows from Precipice Creek, Buckler Burn and Bible Streams.

  The Bible Stream drains a very small catchment northeast of Glenorchy Township. The channel extends from the tow of the hill to Rees Valley Road. The Buckler Burn Stream located at the southern end of the Township, drains a steep catchment with high debris load. In its lower reaches, it has formed a steep debris fan between the Queenstown-Glenorchy Road Bridge and Lake Wakatipu. Part of Glenorchy is constructed on this debris fan and is therefore susceptible to flooding.

Figure 3.20: Aerial Photograph of Glenorchy. Note the protruding debris fans on which the township is built.

As well as the fan of the Buckler Burn Stream studies have indicated that the delta of Rees River is aggrading and advancing toward Glenorchy. This aggradation is raising the bed of the Rees River which is already high in relation to the surrounding land. Aggradation combined with excess water inflows has the potential to cause the river or stream to shift channel (avulse) creating a danger of water flowing through the Glenorchy township.

- ***Makarora***

  Makarora Township is vulnerable to flooding from two main sources, the Makarora River and the tributary creeks that flow into the Makarora River. While the Makarora river presents a simple inundation hazard the tributary creeks that flow into the river present a much greater hazard. The tributary creeks particularly on the eastern side of the valley experience frequent debris flows. The township of Makarora is constructed partially on the Pipson Creek alluvial fan and partially on the White Creek alluvial fan both of which formed as a result of material flowing down the creek. In 2004 and 2006 debris from floods in Pipson Creek buried the SH6 bridge, just north of the Makarora township.

3.5.3 DAM FAILURE FLOODS

Although dam failures are rare, the effects can be significant. Detention dams are built either for electricity generation or for flood protection and are usually engineered to withstand strong forces. However, if the dam fails or if a larger than expected flood occurs, then that structure will be overtopped (eventually causing the dam to fail) and a tremendous amount of water will be released. Floods resulting from dam failures can be more devastating to a vulnerable community than any other type of flood just because of the tremendous amount of energy involved in the sudden catastrophic release of excess water. There are water detention dams at the outlet of Lake Wanaka, and Lake Hawea. If the detention dams on Lake Hawea were to fail then the community of Hawea Flat would be inundated by water within a matter of seconds. The detention dam of Lake Wanaka also creates a significant hazard for the people in Albert town.

Figure 3.20: Young River Rockfall with the newly formed lake behind it (Source: QLDC)

Dam failures need not be restricted to artificial dams built by man, but can also involve landslide dams which are formed as a result of a landslide blocking the course of a river or stream. An example of this occurred in August 2007 when a landslide blocked the course of the Young River. As a consequence a lake formed behind the dam, containing about 26 million cubic meters of water. Fortunately the rising water overtopped the landslide dam and the lake slowly drained away through a natural channel. However, the outcome could just have easily been different had there been a catastrophic failure of the dam. Due to the unpredictable nature of landslides it is difficult to predict where a landslide dam will next occur.

3.5.4 SEICHE EFFECTS

A seiche created as a result of an earthquake or landslide event is likely to devastate any communities located along the shorelines. Depending on the height of the phenomena effects may range from unnoticeable to devastating. All the lakes in the Queenstown Lakes District have the potential to generate these types of waves and if one were to be created it would only take a matter of seconds until it reached a populated area. Seiche effects can exacerbate the flooding hazard as they are giant waves. The water levels don’t just rise but the water hits structures in surges creating significantly more damage to infrastructure.

3.5.5 EMERGENCY MANAGEMENT IMPLICATIONS

Flooding hazards apart from dam failure floods and seiche effects generally occur with advance warning from the New Zealand Meteorological Service. Flooding hazards generally have a defined area (refer to flooding hazard maps). Due to their proximity to one another both Lake Wakatipu and Lake Wanaka have the potential to flood simultaneously, so although restricted to a defined area the hazard of flooding is generally experienced throughout the district.

CHAPTER FOUR
LIFELINES

4.1 INTRODUCTION

Imagine a world without electricity, without a clean and safe water supply, without efficient sewage removal, without phones or other telecommunication devices. What would happen if there is no one to respond to your 111 emergency calls? What would happen if you can't get to a hospital? These are just some of the questions that need to be answered because after a major disaster much of the infrastructure that support these services will be damaged and it could take weeks, months or even years for the services to return to normal. These infrastructure and services that we generally take for granted, but use everyday are directly associated with the quality of life that we live. They are support networks that keep people alive, they are our lifelines!

Lifelines are infrastructure networks that support lives and businesses within a community. Lifelines include electricity, telecommunication, water supply, wastewater removal, transportation and emergency services. These lifelines are often taken for granted with most people unaware of the vast network of underground pipes and other infrastructure that is involved in their operation. In the event of a disaster or other unforeseen situation these services can quickly and without notice cease to function.

Lifelines are extremely important as we generally use them everyday. Take electricity for example, like air and water we tend to take electricity for granted. Electricity is used to light and heat up our homes, we use electricity to cook our food, power our computers, TV's, and other electronic devices. These are the most obvious uses of electricity but there is much more. Electricity is also essential for removing sewage, providing water into our homes, and is also important for telecommunication. Unfortunately electricity runs through just about every mechanical device that we use creating a large dependency. Without electricity, life can be very difficult for many people.

Telecommunication is the same. Over the years telecommunication has developed into an essential part of a community's infrastructure with most people unable to live the way they do without their mobile phones and internet. During a major disaster, such as an earthquake it is expected that telecommunication systems will be damaged for a number of days; usually due to the collapse of antennas, buildings and the loss of power. The use and function of communications infrastructure during and after a disaster is not only vital for survivors to establish contact with emergency services but is also important for informative messages to be communicated to the public.

Water is a necessity for life. A person can survive several days, or even weeks, without food, but can only survive a couple of days without water. Water is not only essential for our survival it is also an important part of our daily activities. In our homes we use water for drinking, cooking, cleaning, flushing the toilet, watering the garden and washing (ourselves, our clothes, our cars and our houses). Water is used for fire fighting, irrigation, industrial and manufacturing processes. We use water in vast amounts every day. Most of us take this for granted and are not aware of the vast network of pipes and infrastructure that source, treat, store and distribute drinkable water right into our homes.

The removal and proper treatment of sewage is important in the response to a disaster because, if not managed correctly, sewage can cause outbreaks of life threatening diseases to spread throughout the region. Sewage can not only increase the risk to humans but can also cause adverse effects to the environment.

The Queenstown Lakes District is heavily reliant on the surrounding transportation network. Isolated within the mountain ranges of the Southern Alps the only way into or out of Queenstown Lakes district is via land or air. Most products and services including food, petrol and medications in the Queenstown Lakes District are sourced from outside of the district. The transportation of these goods and services is the key to the districts survival. Disruption in delivery of these products can have a drastic impact on the health of communities inside the district.

Emergency services are organisations that ensure public safety by addressing different emergencies. Some agencies such as Civil Defence exist solely for addressing certain types of emergencies while others (police, fire, ambulance) deal with everyday emergencies as part of their normal responsibilities. The availability of emergency services and trained personnel are essential when responding to a major disaster in order to preserve life.

The lifelines chapter provides a brief description of the services that are provided in the district and their vulnerability to the natural hazards discussed in the previous chapter. For each lifeline best management principles have been written with the attempt that it will give the reader an idea of how long it will take for the lifeline to be restored with respect to each individual hazard. Unfortunately due to the vast amounts of information collected in the investigation of these lifelines a lot of the background material and pictures/diagrams have been placed in the appendix. Of most importance are the network diagrams of the water supply and sewage systems, as these illustrate clearly the importance of each individual component.

4.2 ELECTRICITY

4.2.1 BRIEF DESCRIPTION

The Queenstown Lakes District is supplied with electricity from outside of the district through a nationwide network of transmission lines called the national grid. The national grid is responsible for transmitting electricity from the power stations to transformer substations located near a populated area. There are two transformer substations that supply the Queenstown Lakes District with electricity, one in Frankton and one at Cromwell. Frankton substation primarily supplies Queenstown, Glenorchy, Arrowtown and surrounding areas with electricity, whereas the Cromwell substation supplies the entire district (including the supply to the Frankton substation). The Cromwell substation is therefore considered to be more important than the substation at Frankton.

The Cromwell substation receives electricity from two 220kV transmission lines. One line comes from the south travelling up through the Clutha valley on the flanks of the Old Man Range via Clyde from Roxburgh. The second high voltage transmission line comes from the north travelling through the Lindis Valley from Twizel. Two high voltage transmission lines feeding into the same substation provides some redundancy to the system, whereby an outage on one line (depending on the day/time of year) may not affect the supply into the district. However, if there are failures across both lines then electricity supply may be lost for several weeks until the damaged components are fixed.

The Frankton substation is supplied with electricity from the national grid via Cromwell through a single 110kV transmission line. This line travels down through the steep and narrow Kawarau Gorge which is renowned for its rockfalls and landslides. As there is only one transmission line feeding into the Frankton substation, electricity supply along this route is considered more vulnerable.

From the transformer substations at Frankton and Cromwell electricity is then distributed throughout the district. The Queenstown area is supplied with electricity via three 33kV transmission lines from Frankton. Two of these lines are beside SH6A on Queenstown Hill and the third goes along the Shotover River through Arthurs Point. All three lines combine at the main area substation behind the Queenstown Primary School. In Wanaka the power is supplied via two 66kV transmission lines from Cromwell. These lines run on either side of Lake Dunstan and join at Queensbury before going to the Wanaka substation along Ballantyne Road.

Other communities within the district are generally supplied by 11kV feeder lines from the Queenstown and Wanaka substations apart from Kingston who is supplied with electricity from the south by The Power Company Ltd. Before electricity is supplied to consumers it may pass through another series of transformers that transforms the voltage to 240V for the low voltage network.

4.2.2 VULNERABILITY ASSESSMENT

The electricity network is of extreme importance to a community, especially after a disaster. Not only is it critical for people to stay warm, cook food and provide lighting but it also allows other lifelines such as water, sewerage and communication networks to be restored as they are all completely dependent on a functioning electricity network. Widespread outages of power shortages can last up to several weeks or more after particular hazards. The most probable causes of such damage may result from very strong earthquakes or meteorological hazards.

- ***Vulnerability to Earthquake***

  The effect of an earthquake on the electricity network will cause widespread power outages and are likely to be the main cause of urban fires within the district. More than any other natural hazard a major earthquake presents the greatest risk to the electricity network. Unlike other hazards earthquakes are capable of damaging all of the components (above ground and below ground) within the system and not only within the Queenstown Lakes District, but also throughout neighbouring districts. Although this thesis acknowledges the risk to the network from damage to infrastructure outside of the district, it primarily focuses on the vulnerabilities found within the Queenstown Lakes District. There are two components of the electricity network that are more vulnerable to earthquake damage than the rest, these being the transmission and distribution components.

  The majority of the power stations that supply the Queenstown Lakes District with electricity are located outside of the district and have been specifically designed to withstand the effects of a large earthquake. (For example, the Clyde Dam located in Central Otago has been designed to very high standards and is able to resist shaking up to intensity IX on the Modified Mercalli Scale). The individual components within these power stations are also expected to perform normally during an earthquake. In the event that a power station is damaged, other generation stations throughout the country are likely to be able to support the extra demand of the system. This however is dependent on a number of other conditions such as lake levels for the hydro electric schemes, damage sustained to other generation stations, demand of the system at the time, proper maintenance and functioning of other system components etc.

If electricity generation can not meet the demand of the system then electricity supply will be disrupted, not only within the Queenstown Lakes District but in areas throughout the country. Unfortunately due to the unpredictable nature of the damage caused by earthquakes, the exact performance of the electricity generation component can not be precisely predicted but in general it is expected that the majority of power stations should perform as normal during and immediately following an earthquake.

The high voltage transmission network that transports electricity from the power station to the local substations is the most vulnerable component in the electricity network due to there widespread nature. Transmission lines and the supporting towers themselves have been designed to respond relatively well to seismic shaking, due to their high strength to weight ratio (Transpower, 2007). Damage therefore, is more likely to be the result of seismically triggered landslides and rockfalls. In saying this however, transmission towers have been adequately founded and designed to resist these hazards as much as possible.

Substations within the district vary in age from 40 years to 10 years old. All are well built using reinforced concrete block construction and are designed structurally to survive an earthquake with minimal damage. The majority of individual components within substations are also designed to withstand the effects of an earthquake. Some components however are much more vulnerable. These include circuit breakers, bushings and those components that utilise porcelain materials. Control cabinets within these substations have been securely mounted and are unlikely to suffer major damage.

The individual components that are vulnerable to the effects of earthquake shaking are generally easily repairable or replaceable. The other components however may take several weeks to repair if damaged, as most materials are sourced from overseas. Substations are critical components within an electricity network and although their vulnerability is low a major failure could mean a loss of electricity to a large amount of people for an extended period of time.

The distribution components such as the 11kV transmission lines are also highly vulnerable to the effects of an earthquake. However, unlike other components of the system generally a single failure will only cause disruption to a small number of people, but if there are multiple failures to the system then the effects can be just as devastating. The most likely causes of failure of the distribution network would be due to poles moving out of alignment. This will occur to poles that are subjected to sideways strain due to liquefaction, land subsidence or severe ground shaking. This suggests that areas such as Frankton, Lake Hayes, Glenorchy and parts of Wanaka that are prone to liquefaction will have more failures. Pole mounted transformers are at an increased risk of failure as their high centre of gravity will make them lean or break more readily. Overhead line and insulator damage may occur if poles move out of alignment.

Underground cables are expected to perform well in an earthquake as they have been designed in redundant loops to reduce the effect of damage, although again damage can be expected where cables are stretched as a result of ground movement or liquefaction. Some cable strain may occur where underground cables rise directly from the ground without slack and are supported or terminated on ground-mounted equipment, such as at external pad-mounted transformers which are connected directly to underground cables. It is possible for the cable tension to also break the transformer bushings; at the base of power poles supporting cables connected to the overhead system and in kiosks where underground cables connect directly onto low and high voltage switchgear. These problems are less likely to occur at substations as the cables are generally supported in an open trench system and have the freedom to move if required. Ground mounted equipment such as transformers and low voltage link boxes are expected to perform as normal during earthquake.

- ***Vulnerability to Mass Movement***

  The effect of mass movements on the electricity network has the potential to disrupt power for a number of days. Unfortunately the actual effects of a mass movement on the electricity system are difficult to predict due to the fact that we do not know where the next mass movement will take place, what type it will be or at what scale. Components located in the path of a mass movement are likely to be severely damaged but again the actual effect will be dependent on the type of movement and scale of the event. Due to their widespread nature, the components most likely to be affected by land movement are the transmission and distribution networks. These components traverse great distances and some are located in areas that are prone to instability.

  Electricity generation is not directly affected by mass movement and thus has a negligible to low vulnerability.

Due to their widespread nature and the difficult terrain that they have to traverse, electricity transmission lines are the most vulnerable component of the electricity system to mass movement hazards. The routes that are prone to instability and particularly susceptible to mass movements include Lindis Pass and Kawarau Gorge. Although every effort has been made to make sure that transmission towers have been founded on solid material, it is next to impossible to remove the risk altogether just because of the nature of the underlying geology. If a mass movement occurs and the foundation of a transmission tower or distribution pole is insufficient to support the wires that carry electricity from one place to another, the network will fail and electricity supply will be disrupted.

There are no substations located in areas identified as being susceptible to mass movements and therefore the vulnerability is considered low.

Overhead and underground distribution lines like the transmission components are particularly vulnerable to the mass movement hazards due to their wide spread nature and underlying geology. The routes that are particularly vulnerably to mass movement related disruption include the route across Frankton Arm, along the eastern shore of Lake Wakatipu (along the road to Glenorchy and Kingston) and areas around Arthurs Point.

Other distribution components of the electricity network are not as vulnerable to mass movements as the transmission and distribution components. However if a large scale movement were to occur within a residential area then obviously transformers, switchgear and other low voltage equipment in that area will be severely damaged.

- ***Vulnerability to Meteorological Hazards***

  The effect of meteorological hazards on the electricity network is widespread due to the fact the meteorological hazards affect multiple areas simultaneously. The vulnerability of the electricity network is made worse by the fact that when there is a failure, restoration will not be able to begin until the event subsides. This means that power could be disrupted for a number of days, possibly even weeks after the initial onset of the event. The most likely events that could disrupt supply are strong winds and snowstorms. Other meteorological hazards such as heavy rain have the potential to cause secondary hazards like flooding or mass movements but currently don’t present a direct risk to the network. Many of the components of the electricity network have been built to resist the extreme effects of the weather, however most of the damage that occurs during meteorological events is actually caused by wind blown debris or falling trees. The components that are quite vulnerable to meteorological hazards include substations and overhead distribution services. High voltage transmission lines have also been known to fail during extreme weather events, however the vulnerability is considered to be less severe than that of substations and overhead distribution lines.

Electricity generation is not directly affects by meteorological hazards however heavy rain may cause the water levels in the lakes to rise and therefore hydro-electric structures will need to be closely monitored so that if water levels get to high they can release the water in accordance with dam safety procedures.

Most transmission lines are not vulnerable to snow loadings or strong gusts of wind, as their built strength has been designed to withstand twice the amount of force of that given in worst case scenarios which themselves seldom if ever occur. Occasionally during windstorms flashovers can occur when conductors are blown to close to one another. Snowstorms can also cause flashovers when snow suddenly falls from a lower conductor, allowing it to rebound hitting a conductor above it. Fortunately fuses and circuit breakers at substations prevent any major damage being done to the systems.

The greatest risk to electricity transmission components with respect to meteorological hazards results from when debris is lifted into the air and blown in to transmission lines. This has the potential to cause lines to break and disrupt the supply of electricity into the district. Heavy rain does not directly affect the electricity transmission components however it may cause the soils that are supporting the transmission poles to become over saturated with water leading to mass movement and support failure.

Substation buildings and equipment are not highly vulnerable to damage from strong winds, except perhaps for some broken windows. However, there is a greater risk to substations from the flying debris that is carried by strong winds (such as roofing, bits of wood etc). If flying debris were to hit equipment or the adjacent building it may significantly damage components or cause flashovers which would cause a loss of power to the affected area. Also debris entering buildings through windows could cause damage to control equipment. Heavy rain or snowstorms are unlikely to affect the substations at all except for the fact that may make it difficult to access some stations due to roads being blocked by debris or washed out by heavy rain etc.

Electricity distribution components particularly overhead distribution lines are at high risk from strong winds and snowstorms. Pole lines are designed to withstand strong wind speeds that are typical of the area and are therefore exposed to wind damage when speeds are in excess of the norm. Most damage results from when falling trees and debris are blown into the lines. Overhead distribution lines are also designed to withstand strong snow loadings particularly in an area with frequent snowfalls. However, similarly to windstorms distribution poles are only designed to withstand the effects characteristic of the area and most damage comes as a result of falling trees or branches that have become overloaded with snow.

Pole mounted transformers are at risk from failing in strong winds because of the transformers large surface area and the relatively high centre of gravity of the structure. These transformers are generally limited to rural areas and the majority of transformers in the Queenstown Lakes District are mounted on the ground. These transformers along with underground services and the rest of the distribution components are largely unaffected by meteorological hazards (even from the risks arising from wind blown debris).

- ***Vulnerability to Flooding***

  The effect of flooding on the electricity network will cause local distribution failures and if not managed correctly can cause fires. The components that are predominantly at risk are those that are situated in areas next to Lakes Wakatipu and Wanaka. These include the Queenstown and Wanaka central business districts and the communities of Glenorchy and Kingston. The distribution system is the most vulnerable component of the electricity network due to its proximity to the water. Other components of the electricity network are not as vulnerable to flooding as they are generally out of the reach of floodwaters.

  Water conducts electricity therefore any introduction of water into the electricity system could force the system component to short circuit sending surges of electricity back down the electricity line which has the potential to damage equipment and ignite anything located close to an electrical connection. The existence of water is not the only hazard to the electrical system during a flooding event. Debris material such as wood and plastics generally create a more significant hazard as collisions could cause further damage to electrical components. Waves on the glacial lakes also have a significant effect as not only is the force of the water greater but the run-up length is also much higher.

Electricity generation stations such as hydro-electric stations, have a low risk of damage from flooding as these structures have been specifically designed so that they can strictly control the surrounding water. For example most hydro electric detention structures have sluice gates that can be opened during times of high flow. The occurrence of debris and waves on these structures will also have minimal effect due to there high built strength. If there are excessively high flows, communities downstream of the hydro-structure such as Albert Town (with respect to the Lake Hawea detention dam) may be at risk. This however is highly unlikely as long as lake levels are monitored closely and that dam safety procedures are followed.

The high voltage transmission network has very little risk to flooding as transmission lines are raised above inundation levels and the supporting towers that are built within flood plains or on river beds are very strong and have been built to withstand strong currents associated with flooding events. Debris and wave action are also not of major concern to the high voltage transmission network due to the high strength of the supporting towers.

All substations within the Queenstown Lakes District are located on land above the predicted maximum flood levels.

The distribution network is the most vulnerable component of the electricity network during flooding events as many components lie at ground level and some of them are even located in the natural floodable margins. Overhead distribution lines should perform relatively well during a flooding event as they are raised above the level at which the flood waters will rise. The supporting poles also should perform well as long as they have been well founded and that there is enough material at the base of the pole to resist erosion. The vulnerability of these poles increases slightly when wave action and debris becomes involved. However due to the relative high strength of these poles and the small surface area transmission lines should remain largely unaffected.

The distribution equipment that is vulnerable to flooding include: ground mounted transformers, switchgear and the low voltage underground network including low voltage link boxes. These components are extremely vulnerable to inundation and must be switched off before becoming inundated. The transformers and switchgear that have been assessed as being high risk in Queenstown are those that are located in areas susceptible to inundation. These include the Steamer Wharf, Town Pier, Marine Parade and the Church Street Mall areas. In Wanaka the transformers at New World and next to the Mee building have been identified as being at risk from inundation.

The majority of the low voltage link boxes within the Queenstown and Wanaka central business districts are in above ground boxes, which are not waterproof. Delta (company that maintains the distribution network), believe there are only three waterproof low voltage boxes currently within the Queenstown CBD. Waterproof low voltage boxes are place underground with a bell shaped lid. The bell shaped lid provides the waterproofing by trapping air within, ensuring water cannot enter. These underground types are very expensive and would only be installed where a retailer/developer has opted to pay for the link box to be placed underground because of access to the premises or some other commercial reason.

4.2.3 ELECTRICITY MANAGEMENT

Electricity supply is one of the most critical services to reinstate after a major disaster because many of the other lifelines are dependant on its continuing function. The national grid including the substations at Cromwell and Frankton is owned and maintained by Transpower New Zealand Ltd. The distribution network is owned by Aurora Energy Ltd and is maintained by Delta Utility Services Ltd under contract. During an emergency it is likely that other contractors will be called upon to work on the networks.

Management of the electricity network will require rapid identification of damaged components and quick response to reinstate transmission and distribution networks and to fix broken transformers. To estimate the amount of time the system will take to restore, routine operation and maintenance times have been listed below. These times however correspond to a single failure and do not take into consideration availability of resources, other repairs needed to the system, or the dependence on the transportation network. These restoration times are only to be used as a rough guide only as Transpower New Zealand Ltd and Delta Utility Services Ltd does not guarantee that repairs can be made within these time frames.

COMPONENT	RESTORATION TIME
Underground Cabling	2 days to 4 days
Transmission and Distribution Lines	2 days to 4 days
Termination Towers	2 days to 4 days
Gantries	2 days to 4 days
Buswork	2 days to 4 days
Control Cabinets and Panels	2 days to 4 days
Communication Towers	4 days to 1 week
Circuit Breakers	4 days to 1 week
Reactors	1 week to 2 weeks
CTs/VTs	2 weeks to 1 month
Buildings	2 Months to 4 months
Transformers	18 Months to 2 years

- ***Management of an Earthquake Event***

  In the event of an earthquake, Transpower will be responsible for the assessment and restoration of the 'National Grid' including the substations at Cromwell and Frankton. Transpower's 'National Grid' is a nationwide system and thus during a major earthquake where there is likely to be multiple failures, the responses will need to be prioritised. Prioritisation will be based on a number of factors including how many consumers are affected, the importance of the routes (e.g. connections to power stations, communities with hospitals or other critical facilities etc) and the ease of restoration. Access to components is likely to be severely compromised during an earthquake and therefore restoration of components that can be reached immediately may be undertaken before components that may take days to reach.

  Most of the spare components for the national grid are located within Transpower's warehouse in Christchurch. Although Transpower is confident that they will have enough resources that can temporarily restore electricity supply such as temporary transmission towers, more permanent structures will need to be sourced from overseas.

  Responses will be co-ordinated either from the Hamilton or Wellington centres (assuming centres are not damaged themselves) with teams being deployed from Christchurch. Due to the limited access into the district, assessment and restoration of Transpower's substations are likely to be time consuming and may need to be carried out by other contractors within the area. Many of the components within the substations that are vulnerable to earthquake shaking will be easily replaced with spare parts located within the region. However, some components within substations are particularly difficult to replace as they will need to be sourced from overseas which can take up to 18 months. These components are generally designed to withstand the effects of earthquakes.

Transpower New Zealand has a policy to maintain power supplies during and after an earthquake, and that if supply is lost it is the company's goal is to ensure that power is restored to earthquake affected areas within 3 days. Transpower also state that involvement with a number of lifeline studies has provided a broader insight into the effects of these hazards and has led to identification of specific concerns that are continually being improved. Some of the mitigation strategies include seismic upgrading of equipment and buildings, review of seismic design standards, ensuring adequate contingency plans are in place for the operation and repair of the transmission system and to ensure the availability of experience service personnel.

Delta Utility Services will be responsible for assessing and restoring the electricity distribution network in the district in the event of a major earthquake. Similarly, to the management of the 'National Grid' where there are likely to be multiple failures, responses will need to be prioritised and they are likely to be prioritised on the basis of the factors described above. It is unclear whether Delta will have enough supplies to fully reinstate the electricity network in the district due to the unpredictability of earthquakes. It is likely that resources such as transmission poles will need to be sourced from neighbouring districts. Delta has advised that they should have enough stock to replace vulnerable substation components.

- ***Management of a Mass Movement Event***

  In the event of a mass movement, either Transpower or Delta Utility Services will be responsible for assessing and repairing the damage to the electricity system depending on the component that is damaged. It is highly unlikely that one mass movement event will be capable of destroying transmission and distribution components, meaning that Transpower and Delta will need to respond. However if this is the case priorities that will need to be addressed will be based upon the importance of the damaged component. For example, a transmission line supplying a township with electricity will have precedence over a distribution cable that supplies a street. In most situations, however, it is likely that between Transpower and Delta enough resources can be utilised to work on different components at the same time.

  Restoration of the electricity supply after a mass movement can be impeded by such factors as the time of the day it occurs, the extent of the damage and the ease of access to damaged components. For example it the movement occurs at night, damage assessment will be delayed until daylight. Before any remedial work begins in the area the site will have to be examined by geologists and engineers, entry into the area will be prohibited or restricted until specialists give the all clear. Geologists and engineers will also need to be consulted when re-routeing transmission lines.

Another limitation that may hinder responses will be the weather. The weather plays an important role in the management of a mass movement as heavy rain may cause the land to become even more unstable and strong winds are likely to make restoration measures dangerous especially if helicopters are needed. Spare transmission components are located in Transpower's Christchurch warehouse and restoration may be delayed until they are transported down.

Fortunately mass movements generally only affect a limited area and therefore restoration of these lines should be relatively straight forward. However, there may be some situations where the landslide is so widespread that an alternative route may need to be established. In either case as long as there are no extenuating circumstances such as bad weather, it is expected that electricity supply will be restored within 3 days.

- ***Management of a Meteorological Event***

  In the event of a meteorological hazard such as strong winds or heavy snow, electricity companies will have the responsibility of identifying system faults and responding to them as soon as it is safe to do so.

  There are several mitigation measures that can be employed to reduce the effect of meteorological hazards on the electricity system. These measures include ensuring that trees and other foliage is a distance away from transmission and distribution lines; having adequate amounts of spare parts available and also ensuring that loose building materials that could become flying missiles are securely fastened before the storms arrive. Placing transmission and distribution lines underground would eliminate the risk of flying debris damaging these components; however it is not always cost effective.

  When responding to a meteorological hazard there is likely to be a great deal of debris littering the roads, some roads may even be blocked. The length of time to restore a damaged component is almost completely dependant on the state of the transportation network and the length of time it takes for the storm to pass over the area. As restoration activities are unlikely to begin until it has stopped raining or snowing or until the wind has abated.

- ***Management of a Flooding Event***

  In the event of a flood, Delta Utility Services will be responsible for shutting down the ground mounted transformers and the associated low voltage network within the Wanaka and Queenstown CBD and other affected areas, when they are at imminent risk of inundation. This will isolate the low voltage distribution network from the rest of the system thus avoiding the dangers of the system short circuiting, however it will also cause a loss of power to consumers located within the affected areas. Although power will be lost to the area, the effects are likely to be minimal as much of the area will be evacuated and essential lifeline components located within these area that are connected to the electricity system such as sewerage pumping stations and telephone exchanges have backup power generators.

  During a flooding event, Delta will be responsible for monitoring the rising water levels and if any subsequent component becomes exposed to the hazard then it will be Delta's responsibility to shut these down as well.

  As flood waters begin to recede, Delta will be able to begin the restoration process. Before the electrical supply is reinstated, the components in the transformers and low voltage link boxes will have to be dried out. It is expected that during a major flood, some components may need to be repaired or replaced, however adequate supplies should be readily available during such situations.

  Electrical equipment is highly sensitive to moisture, and unfortunately the actual effect to the system can be hard to predict, both during the flood event and after the event. For example, electrical equipment located above the inundation levels may fail, due to the higher than normal atmospheric moisture levels. These unexpected failures can lead to imposed delays to the restoration of the system.

  Restoration of the electricity system will be dependent on the rate at which flood waters are falling and how fast it takes for the components to dry out. Electricity supply should be restored before residents return to the buildings/houses.

  If for some reason the distribution poles are damaged during a flood, temporary structures or replacement poles will be required before supply is restored. There should be adequate resources within the district to manage this situation. Restoration of supply may be impeded by disruptions on the transportation network. It is expected that after a major flood that electricity supply to the entire district should be restored within 6 hours after flood waters have fully receded.

4.3 TELECOMMUNICATION

4.3.1 BRIEF DESCRIPTION

The telephone network uses both wires and wireless methods to deliver voice communications between people and data communications between computers. Wire based communication uses copper wires and fibre-optic cables to provide a link between telephones and exchanges. Wireless communications use technologies such as mobile telephones, pagers, satellites and microwave transmission.

Telecommunication supply to and from the Queenstown Lakes District is provided by a primary fibre optic line through the Kawarau Gorge from Cromwell and a digital microwave system. These fibre optic lines feed into both Queenstown and Wanaka central exchanges a digital microwave transmission system feeds into the Queenstown central exchanges to provide some redundancy to the fibre optic lines. At the present time there is also an additional line being installed from Queenstown to Invercargill that will loop the fibre optic line around the main population centres in the South Island. Once this has been commissioned it will provide partial redundancy to the system, by providing two routes into the Queenstown Lakes District. (i.e. if one section of the loop is severed, the information can be transmitted from the other direction)

From the central exchanges the supply is then distributed to roadside cabinets, access pillars and internal or external termination points by a copper cabling distribution system which acts as “feeder cables” between the components. Some high end users in the district use their own isolated fibre optic distribution system to transmit the supply from the exchange directly into their own premises. The supply then reaches the individual owned and maintained telephone systems and computer/data systems within their own premises.

The mobile telecommunications system uses primarily the same components as the land based telecommunications system however instead of a copper cabling system distributing the supply; cellular base stations (cell towers) and a repeater station located at Queenstown’s central exchange receives cellular signals and transmits them back via wireless technology.

There are three telephone exchanges in the Queenstown Lakes District; two in the Queenstown area, one in Frankton and the other in Central Queenstown near the police station on Camp Street and one in Wanaka on Brownstone Street adjacent to the Caltex petrol station. All of these exchanges operate independently and performance is reported to a network management centre in Christchurch. Network management centres monitor the performance of every telephone exchange, every optical fibre cable, every trunk main, main service within a geographical area. If any component were to fail then these centres will know instantly about the problems and have systems that can activate systems that are built in to recover near normal service as soon as possible. In the unlikely event that someone physically has to go to an exchange to change a part, that person can be dispatched to do it. The three exchanges in the Queenstown Lakes district requires power to function properly but are equipped with a battery powered back up system that can be recharged with portable generators.

4.3.2 VULNERABILITY ASSESSMENT

The telecommunication system is one of the most important services in the Queenstown Lakes District. Telecommunication is used to send important messages across a geographic distance and this service is essential for the efficient and co-ordinated response of emergency services. Communication is essential not only for people to contact emergency services but for officials to inform the public of the situation and providing advice regarding what to do and what not to do during a disaster. Earthquakes present the greatest risk to the telecommunication system as they have the ability to damage the telephone network as well as the broadcast network. In a worst case scenario this could completely cut off communication with communities in the district and with the roading network also being severely disrupted and impassable, some townships particularly the smaller ones could find them selves completely isolated. Flooding and meteorological hazards can also cause severe disruption to the telephone network and broadcast network respectively.

Most components within the telecommunication network are entirely dependent on a functioning electricity supply. For example if local exchanges lose their electricity supply the entire telephone network including cell phones will become inoperable. To mitigate this vulnerability back up generators have been installed at the Queenstown and Wanaka exchanges. Cell phone towers have batteries installed that will last between 6 – 12 hours, however they will still be dependant on the local exchange.

In common with any major disaster, some initial congestion on the communication system is to be expected. Localised events such as flooding can result in network congestion in a local area and cause difficulties for the affected customers in completing calls, but leave the rest of the network operating normally. More widespread events however, such as earthquakes, can cause a general network blockage with a collapse of its ability to function through over-loading. The cellular network is particularly vulnerable to network congestion as cell towers are only able to handle small numbers of callers at a time.

Telecom has developed management procedures that can be used to control overloading by restricting the ability to originate calls. However, Telecom is hesitant to employ such measures unless it is absolutely necessary because blocking calls (load shedding) has an additional risk that some genuine emergency calls may be disallowed. An example of this process occurred during the Edgecumbe earthquake where, because of high levels of calls coming into the area, it was necessary to apply restrictions to calls from selected exchanges (such as International and Auckland exchanges) for several days after the event.

- ***Vulnerability to Earthquake***

  The effect of an earthquake on the telecommunication system will cause widespread disruptions throughout much of the district with most telephone services (telephone, cellular phone, internet and data transmission services) being inoperable. The broadcast network has been designed to withstand the effects of an earthquake more successfully and therefore only a minimal loss of services is expected. The components of the telecommunication system that are most vulnerable to earthquakes are the fibre optic transmission lines and copper cabling distribution systems.

  The fibre optic transmission system that connects exchanges with other exchanges are installed in ducts these are vulnerable in areas subjected to significant ground movement, such as when crossing a fault, in areas subject to liquefaction, or land subsidence. Damage may also occur if a bridge carrying one of these fibre optic cables fails. The telecommunication system in the Queenstown Lakes District is fortunate in that the system has redundancy built into it. Once the secondary fibre optic cable is installed between Queenstown and Invercargill it will provide two routes of communication into the district, so that if one route is severed information can be transmitted via the other route. Additionally the district operates a microwave transmission system so that if both route of the fibre optic cable system are severed then communication can still be made wirelessly. By its widespread nature it is expected that the fibre optic cable is somewhat vulnerable. However the cable itself is reasonably robust and is expected to perform relatively well.

The copper cabling distribution system connects the telephone exchange with the customer. Most of the system is underground, however due to its widespread extent it is highly susceptible to damage. Any cables affected by significant differential ground movement caused by changes in soil types or liquefaction, are likely to be severely damaged and bridge crossings would be especially vulnerable. The telecommunications network makes good use of diversity by means of alternative physical routes and alternative media providing redundancy to the system.

Telephone exchanges within the Queenstown Lakes District are expected to perform well during an earthquake, suffering little damage. Some equipment in these exchanges rely on air conditioning equipment to ensure the temperature does not exceed certain levels. Whilst air conditioning equipment is not operating, temperatures need to be monitored to ensure they do not rise to damaging levels. Air conditioning equipment along with switching equipment is reliant upon power and in some cases a water supply. However, the entire telephone network is dependent on the Queenstown and Wanaka exchanges, so if these should fail then it would completely disable the service to customers. During an earthquake it is expected that telephone exchanges will become unstable due to congestion caused by repeated dialling attempts. Dial tone may be slow to appear.

Disruption of service from some cell sites occurs due to the loss of their fibre optic cable links to the telephone exchange or due to the depletion of battery reserve following the loss of mains power to sites. Little effect is expected on the equipment and masts at the cell sites. Very heavy cellular network congestion for the first two hours, with some relief after three to six hours as service demands are impeded through individual cell phone batteries depleting and the probable lack of mains power for recharging.

The broadcast network may be subjected to support structure failure or antennae misalignment. Where ducts and cables enter buildings in areas subject to liquefaction or settlement, damage may occur due to differential movement between the surrounding ground and the building. Aerial systems for microwave radio could become misaligned even if the supporting structures remain intact, although modern systems are reasonably tolerant of movement. UHF and VHF radio communication will only suffer a minimal loss of service as long as the timber masts at repeater stations do not fail. Traffic congestion on these channels is not a concern.

- ***Vulnerability to Mass Movements***

  The effect of mass movements on the telecommunication network will be minimal due to the redundancies built into the system; including two optical fibre transmission lines and a digital microwave system. Unfortunately the actual effects of a mass movement on the network is unpredictable, however we can expect that any component located in the path of a mass movement will be severely damaged depending on the type of movement and scale of event. The telecommunication components that are particularly vulnerable to mass movements are the fibre optic transmission lines and copper cabling distribution system, due to their widespread occurrence. Although the risk to these components is similar, damage to the distribution system has greater consequences as it doesn't have the redundancy built into the system as the transmission cables do.

  Fibre optic cables and copper distribution line are installed using a number of different methods. In the Queenstown Lakes District most of the cables are installed in duct systems made from PVC with glued or rubber ring joints. The cables and lines conveyed in these duct systems generally have either a lead or plastic sheath. Plastic sheathed cables are more tolerant of minor displacement than lead sheathed cables which are susceptible to sheath cracking in the event of any movement.

  In other more rural areas these cables and lines are sometimes installed in overhead transmission lines similar to those used by the electricity network; sometimes in fact they are connected to the same supporting poles. Because the location of probable mass movements in the district is so widespread and the occurrence of movements unpredictable the vulnerability of the cables and lines are determines on the basis of the distance they are away from the local exchanges in Queenstown and Wanaka. For example the areas with greater vulnerability are those located further away from the local exchanges as there is a greater chance of disruption. These outlying areas include the communities of Kingston, Glenorchy, Makarora, Cardrona and other small townships.

  Telephone exchanges are not considered to be at risk from mass movements as long as the electricity supply is not disrupted. Other distribution components such as access pillars located within residential areas have some risk to mass movements but they will be destroyed along with everything else in the slip area.

The broadcast components on the top of peninsula hill have been solidly built and founded based upon geological and engineering investigations, therefore the site is considered not to be susceptible to the hazard of mass movements.

- ***Vulnerability to Meteorological Hazards***

  The effect of meteorological hazards on the telecommunication system may be widespread as strong winds and snowstorms have the ability to damage components over large areas. The components of the telecommunication system that are particularly vulnerable to meteorological hazards are overhead wires and masts and antennas that are general positioned in exposed places, such as the top of hills. Heavy rain is not likely to affect the telecommunications system at all except for the secondary hazard that it presents in the form of mass movements. Strong winds and snowstorms however are far more dangerous.

  Overhead wires can be damaged through the weight of snow. More commonly they are damaged through tree branches falling across them breaking wires as a result of snow loading. The wooden telephone poles are also vulnerable from snapping if the weight on the wire becomes too great. During strong winds flying debris may cause the wire to break. In the Queenstown Lakes District the majority of the distribution cables are located underground due to the fact that snow is a common occurrence for the district. However, there are a few rural communities that are still reliant on these overhead lines and if this component is damaged then there will be pockets of affected customers throughout the district.

  Telecommunication buildings such as exchange buildings and radio station buildings are expected to survive severe weather events. The roofs at these sites are designed to carry heavy snow loads. During strong winds, windows may be blown in or broken by flying objects, then rain or snow would be able to enter buildings through the broken windows and damage equipment. Broken glass would have to be extricated from equipment during the clean-up after a windstorm. This would pose a risk to the availability of the network as, during the work, equipment could be accidentally disturbed.

  Towers and masts are expected to survive the effects of meteorological hazards as they have been built to withstand the extremely strong forces of wind and snow. For example cellular towers are designed to handle wind speed up to a maximum of 230km/hr with gusts of up to 320km/hr. However, smaller antennas and dipoles attached to these masts could be damaged. This means that some paging, UHF radio networks may be partially disrupted.

Most of Queenstown cell sites do not have standby power generators and many of these could lose their mains power supply. Those that do will fail completely after the battery reserve has been used, unless a portable engine alternator is connected to the cell site. Telecom has a number of transportable engine alternators so it should be possible to keep most cell sites functional unless road access is blocked by snow or fallen trees.

Many customers will lose television reception due to loss of their aerials or satellites. Aerials and satellite may be ripped from houses exposed to strong winds and damage may also be made through flying debris. Satellite service may be disrupted due to the inability to receive signals from the satellite through the storm.

Traffic overloading frequently results during a windstorm or snowstorm. It is expected that the telephone network will be very busy, but shouldn't be catastrophically overloaded. Some exchanges may experience minor load shedding. Loss of some cell sites may increase traffic on other cells, but since most of the telephone network will still be functional, this should not be a problem.

- ***Vulnerability to Flooding***

  The effect of flooding on the telecommunication system will cause any component to short circuit and will either lead to "noising" up of the system or local failure. It is expected that those components inundated with water will fail completely and therefore the telephone network will be inoperable. However since many of the buildings that will be affected will be underwater anyway the impact won't be great. The primary components of the telecommunications system that are vulnerable to the effects of flooding include the roadside cabinets and access pillars that are located in the natural floodable margins of the glacial lakes as well as the termination points of the copper cabling distribution system within buildings.

  Roadside cabinets are almost always located in the road reserve at the fence line. If the flood water rises above 200mm the cabinets will subsequently become inundated and customers will start to progressively lose service. Access pillars are also located next to the fence line in the road reserve however these components only serve up to four customers compared with the roadside cabinets that serve an entire city block. Once the floodwaters rise above 400mm in the access pillars the system will short circuit and faults will begin to occur. Roadside equipment may be isolated before the floodwaters reach the components however once the water penetrates critical components such as any connectors in pillars, connection blocks in cabinets, telephone sockets in houses and internal house wiring (which unfortunately tend to be located at low points on the walls) they may still have to be replaced after the flood subsides. Associated cabling and mounting hardware will have to be hosed down to remove silt and sand, and then dried. The cellular network will remain virtually unaffected.

Repair of cables broken due to scouring of roadways and bridge abutments may have to wait until repair of the road is sufficiently advanced. Customer’s service affected by either immersion of plant or cable breaks should be progressively restored over a period of two days to two months after the flooding subsides.

Telecommunication buried cables are designed to function in wet environments, so the effect on them should be minimal. However, as the depth of the water on the surface increases so to does the static water pressures on cable sheaths, and in some cases this will result in some water penetration, bringing on faults within one or two days after the flood. These will be somewhat randomly distributed in the flooded areas and should only affect a small portion of customers.

Exchange equipment will be at risk as soon as flood levels rise more than 50mm above the exchange floor level. Currently all telecom exchanges in the Queenstown Lakes District are located well above the predicted flood level; the closest exchange to the probable water level is the Queenstown exchange which is located 6m above the expected flood levels. The rest of the telecommunication components will be unaffected by flooding events as these are positioned at high elevations well above the predicted flood level.

In common with all other hazard scenarios, some initial telephone network congestion is expected. During a flood it is expected that the telephone network will be very busy but shouldn’t be catastrophically overloaded. Some exchanges may be subject to minor load shedding and loss of some cell sites may increase traffic on other cells, but since most of the telephone network will still be functional this is not expected to be a problem. It is also important to note that all of the components of the telecommunication system are dependent on a functioning electricity supply and if supply is disrupted the telecommunication services will be disrupted until it is repaired.

Road access to some sites may be impassable for virtually all vehicles and others may only be accessible by high wheel base vehicles such as 4WD’s or trucks. This should not present any great difficulties to the Telecom repair effort, provided there remains access across rivers.

There is absolutely no risk to the Broadcast network in the event of a flooding as all components are located well above maximum predicted flood levels.

4.3.3 TELECOMMUNICATION MANAGEMENT

An operational telecommunication system is vital after a disaster so that important messages can be sent to and from emergency services. People generally expect to use the telecommunications network 24hrs a day, 7 days a week, so restoration of this system will also be important to re-establish a sense of normality. The land based telephone network is owned by Telecom New Zealand and is maintained by DownerEDi Engineering Ltd. In the event of a disaster it will be Downer’s responsibility to restore communication as quickly as possible.

Fortunately much of the telecommunications network is relatively easy to repair and therefore the length of time that communication systems are down should be minimal. In stating this however, all of the telecommunications equipment is critically reliant on a functioning power supply and the ability to easily access network components. Standby power generation equipment is only provided at some locations and these will need to be constantly refuelled, creating an additional dependence on the transportation system. If there is an extended outage in the system it is most likely going to be due to this dependence of other lifelines.

Response times are also dependent on the event as repairs will not be started until it is safe to do so. For example, repairs on inundated components due to flooding will have to wait until waters recede, so during meteorological hazards responses will be carried out after wind and rain abates

- ***Management of an Earthquake Event***

  In the event of an earthquake it will be Downer’s responsibility, with the assistance of Telecom, to identify and assess the damage sustained to the system. Downer will then be responsible for the restoration of the system. In the event that a community becomes totally isolated it will be important to establish some sort of communication method whether it includes restoring public pay phones or by stationing radio equipment at a public site.

The first priority will be the fibre optic transmission lines. These lines, although relatively robust, are particularly vulnerable when they intersect an active fault or cross a bridge, and because they generally provide the primary means of communication for most communities this component will need to be restored first. This will also ensure that communities are not totally isolated for too long a period of time.

Once the transmission components are restored the rest of the system can be addressed. The priority at which each component is restored will be based upon how easily a community can access a phone line. Before reinstating phone service to individual households, phone service to groups of people may be more important. This may mean that cell towers if damaged are reinstated as they can reach a greater number of users. The next service to re-establish will be the connection to the 111 emergency call centres and then finally the copper-cabling distribution network.

Restoration times for the telecommunication system will be dependant upon the state of the transportation network and the electricity system. Restoration is dependant of the transportation system as many roads will be significantly damaged or blocked thereby hampering responses. Obviously if there is no chance or restoring a fault some distance away from contractors then local faults will be addressed in the mean time. A functioning electricity supply is needed for the telecommunication system to function. In some places where back-up generators have been installed.

Restoration of local reticulation (lead sheathed) cables may extend over many months, but virtually all other elements of the telecommunications network may be restored to full capacity within one week. In recent major international disasters such as Hurricane Katrina, cellular phones have proven to be an extremely useful and speedy way for response agencies and utilities to augment their communications systems. In times of disaster it should be considered that responding organisations have use of this system while other customers have restricted access.

- ***Management of a Mass Movement Event***

  In the event of a mass movement the components that are most vulnerable include those that are located within the movement area. For example if a landslide occurs beneath the site of a transmission tower then it is likely that that transmission tower will need to be replaced. Fortunately mass movement only affects a limited area and therefore management can be swift.

In the event of a mass movement, Downer will be responsible for assessing and repairing the damage to the telecommunication system. Restoration of the telecommunication system after a mass movement can be impeded by such factors as what time of the day it occurs, the extent of the damage and the ease of access to damaged components etc. For example it the movement occurs at night, damage assessment will be delayed until daylight. Before any remedial work begins in the area the site will have to be examined by geologists and engineers, entry into the area will be prohibited or restricted until specialists give the all clear. Geologists and engineers will also need to be consulted when re-routeing fibre optic transmission lines. Another limitation that may hinder responses will be the weather. The weather plays an important role in the management of a mass movement as heavy rain may cause the land to become even more unstable. Fortunately mass movements generally only affect a limited area and once the land has been deemed stable the service is likely to be restored within three days.

- ***Management of a Meteorological Event***

  In the event of a meteorological hazard the only components that are vulnerable to the effects are the antennas and masts associated with the microwave transmission and broadcast networks. These components have been built to withstand the effects of strong winds, heavy rain and snowstorms and because of the redundancies built into the system; the effects should be minimal to non-existent. Any major damage sustained to these components will require replacement. This would involve sourcing new parts from different parts of the country, which could take several days.

  When responding to a meteorological hazard there is likely to be a great deal of debris littering the roads, some roads may even be blocked. The length of time to restore a damaged component is almost completely dependant on the state of the transportation network and the length of time it takes for the storm to pass over the area. Restoration activities are unlikely to begin until it has stopped raining or snowing or until the wind has died down. Restoration of the telecommunication system will range from a few hours to three days.

- ***Management of a Flooding Event***

  In the event of a flood, Downer will be responsible for restoring telecommunication services after the flood waters recede. Although the land based telecommunication system within the inundated area will be unusable the effects are likely to be minimal as much of the affected area will be evacuated anyway. Downer can do little during a flooding event to minimise the damage. Rather it will be just a matter of waiting and assessing the damage after the flood waters recede.

The components that have been inundated during the flooding event will need to be dried out before being returned to service. There may be some instances where components will need to be repaired or replaced, however adequate supplies will be readily available during such situations. Telecommunication equipment can be highly sensitive to moisture as it involves transmission of a small electrical current and thus its effects can be difficult to predict. However, through thorough testing of the system the effect is likely to remain minimal. Restoration times will be dependent on the rate at which flood waters are falling and how long it takes for the components to dry out. Land based telecommunication should be restored before residents return to the buildings/houses (within 6 hours after flood waters have fully receded)

4.4 WATER SUPPLY

4.4.1 BRIEF DESCRIPTION

The Queenstown Lakes District has eight public water supply schemes that provide people with water. These schemes are located in Queenstown, Arrowtown, Glenorchy, Lake Hayes, Arthur’s Point, Wanaka, Lake Hawea, and Luggate. Other communities in the district, such as Kingston and Makarora, do not currently have a reticulated water supply, but rely instead on private bores and rainwater collection. Water supply systems within the district can be generally broken down into four main stages; collection, storage, treatment and distribution.

The Queenstown water supply network sources its water via two raw water intakes from Lake Wakatipu, known as the Two-mile and Kelvin Heights intakes. The water is pumped from these intakes to two key reservoirs, Twin Reservoir and Kelvin Heights Reservoir. These two intakes provide a high degree of redundancy within the Queenstown water supply system; because depending on the demand of the system, should the Kelvin Heights supply not be available, the Two-Mile intake in addition to supplying its usual area would be able to supply the storage facilities which serve the Kelvin Heights area and vice versa. Once water is pumped to the two key reservoirs; Twin and Kelvin Heights reservoirs it is spread throughout another seven reservoirs with the help of six pump stations that distribute drinkable water throughout the area. The only treatment the water receives is in the form of chlorine dosing and this is only provided at Twin and Kelvin Heights reservoirs

The Arrowtown Township and the adjacent Millbrook Resort sources its water from two bore holes located close to the Arrow River in the Bush Creek tributary. The bores extract water from a shallow free aquifer where it is pumped into two storage reservoirs at the same location. The Arrowtown water supply system comprises of two storage reservoirs that are located at the same location as the raw water intake. The Arrowtown water supply system conveys water to the entire Arrowtown Township as well as providing water to the adjacent Millbrook Resort under a supply contract. The water doesn't undergo any form of treatment but does have emergency chlorination facilities available if required.

Glenorchy's water is sourced from two adjacent bores near Buckler Burn, south of Glenorchy. The water is pumped via one pump station to a storage tank farm. Glenorchy doesn't have any treatment facilities.

The water for the Lake Hayes water supply scheme is derived from a natural spring along the northern shoreline of Lake Hayes. It is then pumped via a rising main to an elevated storage reservoir. Water is conveyed to the Lake Hayes community via gravity. Water is provided not only to properties within the Lake Hayes estate, but is also provided to properties north of Lake Hayes, along Arrowtown-Lake Hayes road and State Highway 6. The water in the Lake Hayes scheme is also untreated but it does have emergency chlorination facilities available if required

Arthurs Point sources all of its water from two bore holes located on the true right hand side of the Shotover River. Two associated pumps then transport the water into a single storage reservoir located above the township. Water doesn't undergo any form of treatment prior to distribution.

The Wanaka water supply system sources water via three intakes from Lake Wanaka, known as the Roy's Bay, Western and Beacon Point intakes. Water supplied to the area could come from any of these three intakes depending on the demands on the system at the time. However, as with Queenstown's water supply system if a water intake were to fail, strict water rationing would be needed. The Wanaka water supply consists of five reservoirs that provide water to the greater Wanaka area via gravity flow. Treatment in the form of chlorine dosing is provided at all three intakes.

The township of Hawea sources all of its water from a single intake structure located by the control structure at the outlet for Lake Hawea. Water undergoes UV treatment before being distributed throughout the Hawea Township and adjacent rural residential areas. The township of Luggate sources all of its water from the Luggate bore and undergoes no treatment.

4.4.2 VULNERABILITY ASSESSMENT

Clean water for drinking is essential as humans need it to survive. If the human body does not get enough water it will begin to dehydrate. The first sign that someone is dehydrated is the fact that they feel thirsty, more, mild symptoms of dehydration include dry mouth and weakness. Severe symptoms of dehydration range from the inability to sweet or shed tears, sunken eyes to fast heartbeat, coma or death. When a person becomes dehydrated their blood gets thick and it is harder for the heart to pump the blood to vital organs. Not only is clean water essential for human survival but it is also important for cleaning wounds to prevent infection. Infected wounds can become serious especially at times when antibiotics may be limited and health services stretched to the limit.

The water supply system is dependant on a functioning electricity supply, as many of the components rely on this electricity to function. Fire fighters are dependant on the water supply system to extinguish fires especially if it is located away from a natural water source. Earthquakes and mass movements are the hazards the water supply is most vulnerable to as damage to certain components of the system can disrupt supply for years after the event. The importance of the components and the corresponding area that they supply water to is illustrated in the water supply diagrams present earlier in the report.

- ***Vulnerability to Earthquakes***

  The effect of an earthquake on the water supply system will cause major disruption of the water supply service and it is expected that the majority of district will not have a functioning water supply. Those that do have functioning water supplies will have to be cautious as the water quality is expected to be severely affected. The most vulnerable components of the water supply system will be the transportation and distribution network as it is expected the most pipelines will be damaged in some way after a major earthquake. Water supply is likely to be lost for several months after a major earthquake due to the amount of failures that are expected in the distribution network.

  Water collection components such as the raw water intakes and bores are not considered to be at risk from earthquakes as they do not coincide with areas identified as being prone to liquefaction or land subsidence, and buildings have been well built and founded. However, many of these components are located next to natural waterways and although not prone to secondary hazards, they may still be damaged from liquefaction or slumping around lake edges previously unforeseen.

Storage reservoirs are not directly vulnerable to earthquake shaking what they are vulnerable to however are mass movements. An earthquake triggered mass movement can severely damage a reservoir that can disrupt the water supply to a large amount of people simultaneously. Important reservoirs are illustrated by the diagram presented in the appendix. Although no actual reservoir has been identified as being at directly at risk from land movement, the risk can not be over looked due to the highly brittle nature of the rock in the district.

Damage to the transportation and distribution networks through cracked or broken pipelines is likely to be widespread and primarily caused by differential ground movements at soil transition zones and in areas of liquefaction. Earthquake triggered mass movements will also cause a lack of support of some pipelines that will most likely catastrophically fail. Unfortunately, the actual damage that the network will sustain will be dependant on the magnitude and location of the earthquake. Due to the unpredictable nature of earthquakes, exact effects are therefore difficult to predict.

- ***Vulnerability to Mass Movements***

  The effect of mass movements on the water supply system may cause localised outages. The main components vulnerable to mass movements are reservoirs and some of the distribution network. Mass movements have the potential to damage pipelines leaving the water supply untenable. Mass movements are also capable of causing significant damage to reservoirs making them unusable. None of the reservoirs have been identified as being situated in areas prone to landslides but due to the highly brittle nature of the underlying geology the scenario should not be overlooked. Unfortunately because the scale, type and location of a mass movement is difficult to define the actual effect of a mass movement on the water supply system is unpredictable.

- ***Vulnerability to Meteorological Hazards***

  The effect of meteorological hazards on the water supply system will cause very little damage as most of the components of the water supply system are located underground. Heavy snow could cause problems with loss of power, possible aerial damage and access problems to reservoirs. Structural damage to reservoirs and pump houses is not likely to be a problem. Strong winds will cause problems with loss of power. Falling tree branches and trees will block access and possibly damage buildings, reservoirs and aerials. A possible parameter that could be of concern is turbidity. Sometimes during a windstorm event, sediments within lakes Wakatipu and Wanaka can become disturbed leading to problems relating to water quality.

- ***Vulnerability to Flooding***

  The effect of flooding on the water supply system will cause very little physical damage. However the quality of the raw water will become seriously affected due to the failure of the sewage system. The main component of the water supply system that is vulnerable to the effect of flooding is the raw water intakes which are typically located near the lake shore.

  Inundation of the pump station control room and power supplies may lead to a loss of power to the intake and pump failure. The effects of waves on the water supply system may cause damage to intake buildings located alongside its edge. However, even with substantial damage to the building, control valves will continue to operate as required. The effect of pump stations not operating will consequently cause water to be supplied from storage facilities. This will therefore increase the risk of water supplies being depleted, which will decrease fire-fighting resources and increase the risk of the water being contaminated due to lowered contact time during the treatment process.

  The two mile intake in Queenstown and the Roy's Bay intake in Wanaka are considered at risk from flood water inundation due to the elevation of the control room floor. It is expected that once water enters the control room it will cause electrical failures that would stop the pumps from functioning. The water supply system in both Queenstown and Wanaka are still expected to function as there is expected sufficient redundancy within the system provided by other intakes. However, should it be required the council would enforce regulation of the water supply by limiting availability.

  The Bermad valves in Wanaka also have the potential to fail during a flood event due to either; greater than designed water depths or sustained submersion. The effect of these valves failing will be minimal. In the event of a regional power loss intakes and pumps will cease to function and careful regulation of the stored water to the District will have to be made until power is restored

  During a flood event, the raw water quality of lakes Wakatipu and Wanaka will vary significantly and affect the delivery of portable water throughout the region through increased turbidity and biological contaminants due to flushing of the contributing watershed areas and potential discharge or raw sewage from the sewerage system. Therefore the water quality supplied to Queenstown and Wanaka is expected to degrade throughout flooding events. Exposure to water where quality is significantly degraded would potentially lead to an outbreak of disease and ill-health. There is an additional risk of contaminated floodwater infiltrating the system from either the raw water source or back flow from inundated network connections.

In the event of a flood it is expected that the raw water will become seriously degraded and will require extra treatment. If water becomes too degraded then intakes will stop supply and communities will need to rely of resources left in the storage reservoirs. During a flood there will need to be strict management of drinking water throughout the district involving restriction of supply and boil water notices.

The water supply rising mains and distribution networks have been designed to perform normally in the event of inundation.

4.4.3 WATER SUPPLY MANAGEMENT

The water supply system owned by the Queenstown Lakes District Council but is maintained and operated by Delta Utility Services Ltd with the exception of the Lake Hayes Scheme which is maintained and operated by Fulton Hogan Ltd. During a disaster these organisations will have the responsibility to restore the water system if it becomes damaged. Within both these organisations the water supply system is only a small part of their business. For example Delta Utility Services are also responsible for the wastewater network and Fulton Hogan is partly responsible for the transportation network, both of which may be damaged at the same time as the water supply system making their responses more complicated. Some of these responses are mentioned in the scenario section of this report.

Management of the water supply system will require rapid emergency response to reinstate pump, solve any reticulation problems and to contain water. Water management may also require the council to turn off water supply to affected areas, and provide an alternative supply if necessary. To estimate the amount of time the system will take to restore, routine operation and maintenance times have been listed below. These times however correspond to a single failure and do not take into consideration, availability of materials, other repairs needed to the system or other systems within the district such as the wastewater network (e.g. during a major earthquake their maybe over a hundred pipelines damaged, this would mean that it may take several years before the system is restored back to normal).

These restoration times are only to be used as a rough guide only as Delta Utility Services does not guarantee that repairs can be made within these time frames.

RESTORATION ACTIVITY	TIME TAKEN
Blockages	2 hrs to 1 day
Equipment repairs	4 hrs to 1 week
Pipeline repairs	4 hrs to 1 month
Valve and Hydrant Box Repairs	1 day to 1 month
Structural repairs	1 day to 1 month
Reservoir cleaning	1 day to 1 month
Trench Levelling	1 day to 1 month
Relocation	1 day to 1 month
Construction	1 day to 1 month

- ***Management of an Earthquake Event***

  In the event of an earthquake, Delta Utility Services will be responsible for the identification and restoration of damaged components. The components of the water supply system that are most vulnerable to earthquakes are the transportation and distribution pipelines and possibly also the storage reservoirs. Because of the wide spread damage sustained to the pipelines water supply will take years to fully repair.

  Reservoirs may be damaged as a result of seismically triggered mass movements. The implications of a reservoir being unusable can be immense not only are people unable to receive water but fire fighting supplies will also need to be considered. Unlike the underground components it will be easily identifiable if a reservoir is damaged A reservoir is a critical component to the water supply system and Delta Utility Services will need to make the restoration of reservoirs a top priority.

  Pipelines are the most vulnerable component within the water supply system with hundred of failures expected it is likely going to be a time consuming process to identify and reinstate supply. The only way to determine if a pipeline has sustained any damage is to physically inspect the pipeline or to run water through it and see if it gets to the other side. Thus, the identification process will take up a great deal of time and small failures may not be found until several years after the event. For each failure, the pipeline will need to be excavated and repaired/replaced and tested before backfilling. This can take between 4 hours to 1 month to complete (for each failure). Thus restoration of supply could take many years.

Delta Utility services have said that in an event of an earthquake they are unlikely to have adequate spare pipelines available (particularly larger diameter pipelines) and will have to source them from different parts of the country.

In summary the entire water supply system may become untenable and an alternative supply will be needed. Consideration should be given to obtaining and/or storing water in tanker trucks or elsewhere such as from some of the other smaller lakes in the district. Power supply is also likely to be cut to the water supply system therefore the use of generators will need to be examined, taking into consideration that they will need to be refuelled periodically and the fuel supplies may be in high demand.

- ***Management of a Mass Movement Event***

  In the event of a mass movement, Delta Utility Services will have the responsibility of reinstating damaged components. Pipelines can be reinstated within days after the event, however damage to reservoirs could take months. The effect on the system should be minimal as the system has some redundancy built into it where an outage may not affect the entire supply. However if supply is affected it would be the Councils' responsibility to ensure that appropriate management is undertaken. The amount of damage to the system and hence how it would be managed is dependent on where the movement occurs. But a few general conclusions can be made if a reservoir is damaged or completely destroyed during a mass movement then supply to the area that this reservoir services may be out of service. The reservoirs that would have the most impact if destroyed would be the Kelvin Heights and Two-mile reservoirs as these reservoirs are critical in the network.

- ***Management of a Meteorological Event***

  In the event of a meteorological hazard, Delta Utility Services will have the responsibility of monitoring the turbidity levels in the lakes. If turbidity levels rise above accepted norms then pumps will be shut off. Vulnerability arises when there is a widespread electricity loss or if critical access to pump stations or reservoirs are blocked due to fallen trees, debris etc.

- ***Management of a Flooding Event***

  In the event of a flood the components of the water supply system that are most likely to be damaged are the intake structures (particularly the two mile creek intake, and Roy's Bay intake). Fortunately if these structures become inundated because of the redundancies built in the system the other intakes should be able to pick up the residue. However if these pump stations coincidently fail or if the flood levels rise above these structures also (albeit unlikely), then serious problems could develop. Communities will have to rely on the water stored within reservoirs and water restrictions would need to be enforced to ensure adequate supply management.

A mitigation measure that could be put in place before the flooding event involves barricading/ sandbagging the vulnerable entrances to these structures so that it prevents the flood water from entering the structure or at least temporarily hold it back. The longer that these intakes operate the less pressure that it will put on the other intakes. Another concern with water quality is that if it deteriorates too much it would be beneficial to shut down the pumping stations, as occurred during the 1999 flooding event. Thus the community would have to survive on the water that is stored in the reservoirs alone. During normal conditions at full capacity this will last for approximately two days.

Delta Utility Services has said that the chlorine dosing to the system is increased during flood events to address the increase in biological contaminants. A boil-water notice would be issued by the council if the water supply was deemed unacceptable. The council will also carry out intermittent testing of the water and in some cases additional turbidity meters may be installed.

4.5 WASTEWATER

4.5.1 BRIEF DESCRIPTION

Wastewater is used water or any other water that has been adversely affected in quality by contaminants. Contaminants can arise from a number of sources and can come about in a variety of forms and a range of concentrations. Wastewater is the waste from our homes and workplaces and includes excess water that collects on car parks, roads, buildings, driveways and gardens. Any water that is even slightly contaminated is termed wastewater. In the Queenstown Lakes District the wastewater system is divided into two totally separate networks; the stormwater network and the sewerage network.

1. Stormwater is excess water that runs over the ground on its way to the sea. When rain falls on a car park, a building, a road, a driveway or a garden it follows a natural flow path or is collected by a pipe system where it flows downhill until it reaches a natural waterway, such as a river, stream or lake. Stormwater not managed correctly can cause severe damage to the natural and built environment.

2. Sewage generally comprises of liquid waste produced by humans that typically consists of washing water, faeces, urine, laundry waste and other material which goes down drains and toilets from households and industry. It is a major source of pollution especially in densely populated areas and therefore needs to be managed and treated before it is disposed back into the environment.

- ***Stormwater System***

  In the Queenstown Lakes District there are stormwater systems located in Queenstown, Wanaka, Hawea, Albert Town, Arrowtown, Glenorchy, Arthur's Point and Lake Hayes. Other settlements in the district such as Kingston, Luggate and Makarora have limited stormwater infrastructure and typically rely on ground soakage and natural watercourses for their stormwater removal. Stormwater systems in the district typically comprise of street culverts, pipelines and open channels. This stormwater infrastructure is laid down at a downward angle so that the stormwater can flow under the influence of gravity, downhill, until it is discharged directly into a natural waterway such as a river or lake.

  Stormwater in Queenstown is discharged into Lake Wakatipu. In Wanaka stormwater is drained into either Lake Wanaka or the Cardrona River. In Hawea and Albert Town stormwater is drained into Lake Hawea or the Clutha River. Arrowtown's stormwater drains into the Arrow River. Glenorchy's stormwater infrastructure only consists of open water courses and some culverts, stormwater discharges into Lake Wakatipu. Arthur's Point stormwater infrastructure also consists only of water courses and some culverts; stormwater discharges into the Shotover River.

- ***Sewerage System***

  The Queenstown Lakes District has seven public reticulated sewage systems located in Queenstown, Wanaka, Hawea, Albert Town, Arrowtown, Arthur's Point and Lake Hayes. Other settlements in the District such as Glenorchy, Kingston, Luggate and Makarora have limited sewage infrastructure and typically rely on individual septic tanks, package treatment plants and private community schemes for sewerage treatment. The sewage system in the district can be broken down into three main components as illustrated in the following diagram.

  The sewerage system in Queenstown conveys sewage from thirteen catchment areas through the use of eleven pump stations that are located throughout the Arthurs Point, Kelvin Heights, Fernhill, Sunshine Bay, Frankton, Glenda Drive, Quail Rise and central Queenstown areas. The pumping stations eventually convey all the sewage to the

Shotover sewage treatment facilities. However before sewage reaches the oxidation ponds for treatment they pass through two key pumping stations (Marine Parade and Frankton Beach) and a number of smaller ones.

The sewage system in Arrowtown and Lake Hayes conveys sewage from four catchment areas through the use of three pump stations that are located throughout the Arrowtown and Lake Hayes Areas. The pumping stations eventually convey all the sewage to the Shotover oxidation ponds. The Arrowtown pump station receives sewage from the majority of Arrowtown and McDonnell Rd. It is located along Norfolk Street and conveys the sewage to the Bendemeer pump station. Along with Arrowtown’s sewage, the Bendemeer pumping station receives sewage From the Lake Hayes area as well as the sewage from the Millbrook Resort. All the sewage is then conveyed to the Shotover oxidation ponds, which is where all treatment of Arrowtown’s wastewater is carried out.

The sewage system in Wanaka conveys sewage from eight catchment areas through the use of eight pump stations that are located throughout the Beacon Point and Wanaka areas. The pumping stations eventually convey all the sewage to the oxidation ponds on Ballentyne Road.

The sewage system at Albert Town conveys sewage from four catchment areas through the use of three pump stations; aptly named pump stations one, two and three. Pumping station one is one of two pump stations that receives sewage from the majority of Albert town, west of SH6. Pump station three is the second pump station that receives sewage from the west part of Albert town and then conveys it too pump station one. Albert Town east of SH6 sends its sewage too pumping station two. These three pumping stations eventually convey all the sewage to the gravity pipe that leads to the Albert Town treatment ponds.

The sewage system in Hawea conveys sewage from four catchment areas throughout the Hawea region with the use of three pump stations, plus one private catchment and pump station. The pumping stations eventually convey all the sewage to a treatment facility located approximately 2km south of the residential area, between Domain Road and the Hawea River.

4.5.2 VULNERABILITY ASSESSMENT

The wastewater system in the district is vulnerable to a number of hazards but the more devastating hazards include earthquakes and flooding as these hazards are more likely to cause disruption to the system. The effective removal of stormwater is important for public safety, the protection of property and the environment and to minimise disruptions to the ability of a community to use public amenities such as transportation systems. In the absence of a reticulated stormwater system such as those in Kingston and Makaoroa, individual properties must make individual arrangements for stormwater removal. The Queenstown Lakes District is fortunate in that most communities have been developed in steep catchment areas where the natural course of the stormwater is downhill and into the natural waterways in the district. Much of the stormwater infrastructure in the Queenstown Lakes District aids in the removal of stormwater from urban areas where it is likely to pond due to the nature of the surface.

The potential for contaminants to infiltrate the stormwater system from inadequately deposited chemicals is also increased. Pollutants that have been deposited on our roads such as gasoline and oil from vehicle engines, other chemicals that have been left in yards or other properties have a high chance of infiltrating the stormwater system. As there are no stormwater treatment facilities in the Queenstown Lakes District there is a good chance that these pollutants will contaminate the rivers, streams and lakes. This contamination will also have adverse affects on the drinking water which is sourced from many of these natural waterways.

The sewerage system is an important component of infrastructure in the Queenstown Lakes District as it removes raw sewage that carries dangerous contaminants away from the urban population in order to reduce the chance of disease spreading throughout the population. Unfortunately, very few people care about where their waste goes as they have an ‘out of sight out of mind mentality: This can be quite hazardous to a community because if sewage is not managed correctly it has the potential to cause very serious adverse effects. The sewerage system is dependant on a functioning electricity supply at pumping stations otherwise the pumps fail and the wet wells can fill up with sewage. The hazards that the sewerage system is most vulnerable to are earthquakes which can cause great disruption due to the widespread damage of the trunk mains and reticulation and flooding due to the proximity of the pumping stations to the water.

- ***Vulnerability to Earthquakes***

  The effect of an earthquake on the stormwater network is likely to be widespread, however the effects are expected to be minimal as the stormwater network in the district comprises only of reticulation components that are used to transport excess surface runoff to a natural waterway. These culverts, pipelines and open channels are spread throughout the district and because of their widespread nature they are susceptible to earthquake damage. Much of the damage to the stormwater network will be due to differential ground movements especially in areas that are prone to liquefaction. Pipelines and culverts are likely to be cracked or broken. Many of the pipelines will still function but with reduced capacity and a tendency for blockages to occur. Open channels will experience blockages due to either trees or other materials falling into them or through bank slumping.

There is an indirect vulnerability to the stormwater system from earthquake and this results from infiltration of contaminates into the stormwater network due to the widespread damage to buildings. Within many buildings there are stored chemicals, paints and other chemicals applied to the outside of structures. During an earthquake it is likely that excess chemicals will be spilt and these chemicals may drain away through the stormwater network and end up in the natural waterways.

The effect of an earthquake on the sewerage network will be reasonably devastating as it will lead to unavoidable sewage overflows into the streets and into homes with the potential of creating a serious health hazard. The sewerage components that are particularly vulnerable to damage from an earthquake are the trunk lines and reticulation pipelines.

The majority of pumping station buildings are likely to suffer moderate damage with cracking of brittle components such as concrete/ brick/ block walls, but will remain substantially intact. The cracking of the basement or wetwell walls could allow the ingress of water and sewage into the basement and dry wells. Pumping stations rely on electricity to function and with no back up generators many pumping stations are vulnerable. The majority of pumping equipment within pumping stations has a small possibility of damage. It is expected, especially in areas that are prone to liquefaction, that where pipes enter wells and basements there will be damage due to the inability of pipelines to flex. The pumping stations at Marine Parade and Frankton Beach in Queenstown have generators installed should there be a power loss, but these will need to be refuelled periodically. Failure of the pines pump station in Wanaka would lead to a build up of sewage in the main between it and the Pembroke Park pump station, eventually causing the Pembroke Park pump station to also fail.

Buildings associated with the treatment of sewage were found to be at low risk of damage however the risk to the equipment within these buildings would be moderate.

The impact to the oxidation ponds may involve slumping of pond walls and minor damage to pond connection pipes, but overall the impact should be low. The impact of damage to the aerators would be insignificant.

It is expected that an earthquake will cause widespread damage of the reticulation network that link homes and businesses with pump stations throughout the district. There would be numerous broken junctions, broken collars, displaced joints and possible losses of grade. This damage can lead to blockages and pipe failure ultimately leading to the overflow of sewage onto the streets. Pipeline damage will take several months to repair due to the widespread damage. However, it is expected that in most areas, even though the pipelines are severely damaged, that sewage could be kept within sections of these pipelines to ensure they are not released into the environment. This may give the council the much needed time to find and repair damaged pipelines without causing a significant health hazard.

Of greater importance to the sewerage network are the trunk mains that link the pump stations with the treatment facilities. Widespread damage of these pipelines is also to be expected during an earthquake. However, because these lines generally carry greater amounts of sewage and transport the sewage under pressure there is a greater chance of sewage overflow. As well as reticulation failures, pipelines are more vulnerable if they cross areas that are subject to liquefaction and land subsidence

- ***Vulnerability to Mass Movements***

  The effect of mass movements on the stormwater system will cause very little localised damage, as a landslide or any other differential land movement across a pipeline will cause it to rupture. This may also cause more water to infiltrate the ground at the location of the landslide causing it to progress further. Based upon current mapping there are no regions in the Queenstown Lakes District that shows the stormwater system crossing an active landslide area.

  The effect of mass movements on the sewerage system will cause localised damage that may destroy property and create an environmental hazard. The only component of the sewerage network that is vulnerable to mass movement is the reticulation pipelines. Mass movements have the potential to damage pipelines causing sewage to overflow into the streets and making the sewerage system inoperable.

- ***Vulnerability to Meteorological Hazards***

  The effect of meteorological hazards on the stormwater system may cause localised areas to be affected by surface flooding. The stormwater system is vulnerable to meteorological hazards particularly the hazards that involve increased water input such as heavy rainfall and the effects the results from snowmelt. It is unlikely that the stormwater system in the Queenstown Lakes District will be able to cope with the influx of water. This will result is serious public and private property losses and erosion.

  The effect of meteorological hazards on the sewerage network will cause very little damage as most of the components of the sewerage network are located underground. Heavy snow could cause problems with loss of power, and access problems to critical infrastructure. Structural damage to reservoirs and pump houses is not likely to be a problem. Strong winds will cause problems with loss of power. Falling tree branches and trees will block access and possibly damage buildings, albeit minimally.

- ***Vulnerability to Flooding***

  The effect of flooding on the stormwater network will cause serious public and private property losses as the stormwater network is unlikely to cope with the influx of water. The volume and timing of excess surface runoff may cause flooding especially within urban areas that are covered with impervious surfaces (parking lots, roads, buildings). These surfaces do not allow rain to infiltrate the ground and therefore more runoff than normal is generated. This excess runoff can overwhelm stormwater collection systems and overflows can enter the streets.

  The effect of flooding on the sewerage network will cause catastrophic failures of some of the major components that allow sewage to be pumped to treatment facilities. These critical components include pump stations and the reticulation pipelines.

  The risk to the sewerage network arises when excess flood water enters the system. Any extra water that flows into the sewerage system will likely inundate the wet well at the pump stations and will require the pumps to run longer. This can lead to premature failure of the pumps and places additional stress on the trunk mains. Inundation of the pump station control rooms and electrical equipment can also lead to equipment and pump failure. If the pumps fail or are insufficient to transport enough sewage it will cause the wetwell to over flow and raw sewage will be discharged into the environment where it will cause damage to property and become an extremely dangerous environmental hazard. It should be noted that discharged sewage won't be restricted to the proximity of the pumping station but will also back up along the incoming pipes and escape through the manholes onto the streets, and possibly out of sinks and toilets within buildings up stream of the pump station. Whatever the case may be the raw sewage will eventually mix with the flood waters and will probably end up in the basement of lakeside buildings and/or the drinking water supply intakes with consequential health and property damage effects. The pump stations particularly vulnerable to the effects of flooding are the Marine parade and Frankton pump stations in Queenstown and the Pembroke Park pump station in Wanaka.

It is expected that because of their proximity to the lake edge that these pump stations will be covered by floodwaters. The Marine parade pump station although located right on the shoreline of lake Wakatipu is likely to perform relatively well during a flooding event as the wetwell has been sealed by steel plates that are designed to significantly reduce the amount of water that enters the system. The control building at the marine parade pump station is also vulnerable to inundation however to mitigate the effects of the flood safe guards have been installed in the pump station. For example a block wall and a removable stainless steel gate have been fabricated to allow the building to be manually sealed up to 312.85m above sea level. A dewatering pump has been installed in a sump to keep the control building dry and all the control equipment has been elevated. Finally a generator has been installed to provide power in the event of regional or local power loss. Provided the gate, dewatering pump and generator are all operating properly, the pump station should continue to operate as normal. The generator would need to be refuelled periodically.

The floor of the control building and the top of the wetwell at the Frankton Beach pump station are both below the expected flood level. The station does not currently have any of the safeguards that have been used at the marine parade pump station therefore is highly vulnerable from the effects of flooding. The Frankton beach pump station does however have a power generator should there be a regional or local power loss.

The Pembroke Park and Pines pump station in Wanaka is also at risk from inundation of flood waters and currently there are gaps within the control building thereby not making it waterproof. Like the Frankton beach pump station there are currently no safeguards installed within this pump station. Failure of the pines pump station would lead to a build up of sewage in the main between it and the Pembroke Park pump station, eventually causing the Pembroke Park pump station to fail.

None of the sewage treatment facilities in the district are at risk from inundation as they are all located above the predicted maximum height of flood waters.

The primary concern regarding the sewage reticulation systems during flood events is the increased flows caused by the infiltration of flood waters into the system. During flooding events, inundation (as little as 100mm) will find a way into the sewerage system. Flood water may infiltrate the sewerage system through cracks in the pipelines due to the saturated ground conditions; it may flow down drains within buildings (for example, through toilet facilities, sinks and showers etc.); Flood water may flow into manholes that lead into the sewerage system and finally any illegal stormwater drainage connections will also add to the amount of water being added to the system. These increased flows can lead to overloading of the receiving pump stations and sewage overflow.

4.5.3 WASTEWATER MANAGEMENT

The wastewater system (stormwater and sewage systems) in the Queenstown Lakes District is owned by the Queenstown Lakes District Council but is maintained by Delta Utility Services Ltd with the exception of the sewage system at Lake Hayes which is maintained and operated by Fulton Hogan Ltd. Management of the wastewater system will require rapid emergency response to reinstate pumps, solve any reticulation problems and to contain sewage.

In addition to maintaining the wastewater system Delta and Fulton Hogan also manage other lifeline systems. Therefore in a major disaster that damages multiple lifelines such as an earthquake, restoration of damaged components will need to be prioritised. In general, priorities will be based on whether life and/or property are at risk. For example; the water supply system will be given top priority as it is essential for the health and safety of the public. The stormwater system will be a low priority as damage generally does not pose a threat to life or property. The sewage system has a moderate priority. It is important to note however that priorities may change based on the nature of the event.

To estimate the amount of time the system will take to restore, routine operation and maintenance times have been listed below. These times however correspond to a single failure and do not take into consideration, other repairs needed to the system or other systems within the district such as the water supply system (e.g. during a major earthquake their maybe over a hundred pipelines damaged, this would mean that it may take several years before the system is restored back to normal). These restoration times are only to be used as a rough guide only as Delta Utility Services does not guarantee that repairs can be made within these time frames.

RESTORATION ACTIVITY	TIME TAKEN
Blockages	2 hrs to 2 days
Equipment repairs	4 hrs to 1 week
Pipeline repairs	2 hrs to 1 month
Culvert repairs	2 hrs to 1 month
Channel repairs	2 hrs to 2 months
Manhole repairs	2 hrs to 2 months
Structural repairs	1 day to 1 month
Trench levelling	2 days to 2 months
Relocation	7 days to 2 months
Construction	1 month to 6 months

- ***Management of an Earthquake Event***

  In the event of an earthquake, the components that are most vulnerable are the reticulation components and pump stations particularly the Frankton Beach pump station which is located in an area subject to liquefaction and it is critical for the transport of sewage to the treatment ponds. Reticulation however will be the biggest problem particularly those that are situated in areas prone to liquefaction; pipelines are prone to rupturing or cracking when they pass over area of different composition. Unfortunately due to the widespread nature of the reticulation system and the unpredictability of an earthquake, we are unable to determine where the pipelines will break. Regrettably the only way to tell if a pipeline has ruptured is through visual inspection either through the use of closed circuit television cameras or when sewage starts spilling onto the streets.

  If the sewage spills out onto the streets it may create a significant health hazard, but it is more than likely that although there will be many failures of pipelines the sewage will be safe isolated below the streets until service is restored. It is important to note that during an earthquake Delta Utility Services will be responsible for both the water supply and the sewerage network and they have said that during catastrophic failure of both systems priority will be given to the water supply system based on the fact the sewage will be relatively safe hidden below the streets. However in times where sewage spills on to the streets this will be given priority to avoid health scares.

- ***Management of a Mass Movement Event***

  In the event of a mass movement, Delta Utility Services will be responsible for isolating the damaged component cleaning up the sewage overflows and using temporary measure to reinstate the pipeline until more permanent measures can be implemented. Generally geologists will have to ensure that the slide is stable before any remedial work is commenced. This may take up to 12 hours, therefore sewage restoration may take up to 24 hours after the movement occurred.

- Management of a Meteorological Event

  In the event of a meteorological hazard, Delta Utility Services must ensure that if there is a power loss that electricity generation equipment is functioning normally. This will include refuelling every 6 to 12 hours. Access to critical facilities may be hazardous due to flying debris, ice/snow etc. There are no direct impacts to the sewerage system from a meteorological hazard perspective.

- ***Management of a Flooding Event***

  In the event of a flood Delta Utility Services will be responsible for ensuring that pump stations located with in the natural floodable margins do not become overwhelmed with flood water causing the pumps to run over capacity. Mitigation measures that can be employed to reduce the effects of the flood include barricading the pump stations with sand bags. There have been some more permanent measures installed at pump stations that were discussed above. It will be Deltas responsibility to ensure that power is supplied to the pump stations and if necessary that generators are refuelled.

4.6 TRANSPORTATION

4.6.1 BRIEF DESCRIPTION

The transportation system in the Queenstown Lakes District is divided by the mediums in that they use: land transport, water transport and air transport.

- ***Land Transport***

  The roading network in the Queenstown Lakes District can be split into three different systems: state highways, local roads and special purpose roads. State highways are generally roads that form part of the integrated national network of roads that are strategic inter-district routes connecting locations of national significance (for example, large population centres, major ports and airports and major tourist areas) Special purpose roads cater for a high proportion of tourist traffic and are generally those that are being considered for becoming a state highway. All other roads are local roads controlled by territorial authorities.

  The state highways in the district include: State Highway 6 from Haast at the top of the district to Kingston at the bottom of the district via Frankton Flats. State Highway 6a from Frankton to the Park Royal end of Shotover Street. State Highway 84 from State Highway 6 at Mount Iron to Ardmore Street, Wanaka. State highway 8a from State Highway 6 just north of Luggate to State Highway 8 just south of Tarras. Local Roading in the district consists of more than 800km of formed roads (of which over 400KM are sealed), including 91 bridges.

  Bridges in the Queenstown Lakes District provide some of the most the critical links over what could be described as some of the most intense terrain in New Zealand. Bridges close the gaps over steep canyons as well as providing access over a number of river crossings. Unfortunately the link that bridges create make the consequences of bridge damage that much more disrupting to the transportation network. Important bridges in the district to highlight include: the Edith Cavell Bridge and the Lower Shotover Bridge. Arthurs Point Bridge, the twin bridges over the Kawarau River, the Kawarau Bridge at the outlet of Lake Wakatipu and the Albert Town Bridge.

  The Queenstown Lakes District is almost totally reliant on the roading network to deliver freight and other supplies to communities as much of the district has no direct rail access and only very limited air freight capacity.

Freight and supplies come into the district daily via truck to various supermarkets, warehouses and other retailers. Supplies come from either Dunedin or Invercargill and takes roughly 2 - 3 hours. Another resource that is delivered into the district via the roading network is fuel. Fuel itself is considered as a lifeline because of the importance it holds for other services. For example emergency services need fuel for their vehicles, utility services need fuel for back up generators, fuel is also needed for other aircraft and heavy duty construction equipment and much more.

Petroleum products are delivered from bulk tankers that are operated by Silver Fern Shipping Ltd twice a month from the Marsden Point Refinery. A typical run would unload fuel at Timaru, Dunedin and Bluff. The fuel would then be loaded on to tanker trucks and distributed throughout the district. The Queenstown Lakes District is generally supplied with fuel out of Bluff however it is not uncommon to see them delivered out of Dunedin when storage tanks are low.

- ***Water Transport***

  In the Queenstown Lakes District water transportation is used everyday. It is particularly popular with tourists who experience recreational activities such as jet boating or rafting and scenic tours such as a trip on the vintage steamship the TSS Earnslaw. Residents that own their own boat sometimes use it to collect supplies from stores located across the lakes otherwise they use it for recreational purposes.

  Water transportation is widely used on the glacier lakes with Lakes Wakatipu, Wanaka, and Hawea all having permanent jetty berths available. Most lakes in the area also have boat ramps. In the event of a major disaster these major waterways may provide access to areas that have been isolated from road-slips. It may even prove vital in the transportation of goods and services throughout the district.

- ***Air Transport***

  The fastest way into and out of the Queenstown Lakes District is by air. Aeroplanes and helicopters are abundant and widespread in the district due to the high levels of tourism in the region. Currently there are two airports in the district located in Queenstown and on the outskirts of Wanaka. Queenstown airport is essentially the main airport as most commercial flights land there. Wanaka acts more as a supporting airport and although it is used for some commercial flights it is mostly used for recreational activities such as sightseeing flights. During a major disaster such as an earthquake air transportation will become a critical link in the provision of supplies and the transportation of people

4.6.2 VULNERABILITY ASSESSMENT

The Queenstown Lakes District is highly vulnerable to transportation network disruption due to the nature of the surrounding environment and its isolation. This isolation is a reason why Queenstown is such a popular tourist destination. However it is also the reason why communities are at such great risk. The ability to move people and goods from one place to another is perhaps the most important process that occurs within these communities and for most of them is the key to their survival. The greatest risks to the transportation system come from the effect of earthquakes and meteorological hazards. There are some roads in the district that are important to highlight due to their specific vulnerability to natural hazards. These include:

The road between Cromwell and Queenstown. This road is part of State Highway six and is the primary access route to Queenstown from the east. A fair portion of this 60km stretch of highway travels high above the swift flowing Kawarau River which is located at the bottom of a steep narrow gorge. Drivers are required to negotiate several tight bend and corners and from April to October ice and snow can significantly this affect this road. This stretch of road is also highly susceptible to rockfalls. The Kawarau Bridge that crosses the Kawarau River is a major weak link of the transportation system damage to this bridge would completely severe access from the east.

Malaghan Road that connects Queenstown with Arrowtown via Arthurs point is also another transportation route in the district. The road crosses the Shotover River over the single lane, Edith Cavell Bridge. Built in 1918 this bridge replaced two wooden bridges further up the gorge. Similarly to the Kawarau Bridge this crossing presents a dangerous vulnerability to the transportation system damage to this bridge would completely severe this arterial link to Arthurs Point and Arrowtown. Fortunately there is a second route to these towns via Lake Hayes.

The road into Skippers Canyon also presents a concern during a disaster. Popular with tourists this road unsealed, dangerously narrow and has blind corners. Jagged rock faces to the left and sheer drops to the right the road has never been a road for the incompetent, inexperienced or nervous drivers. The road is also frequently blocked by landslips and during winter it can be icy and boggy.

Finally, the Crown Range Road that transverses the Cardrona Valley and connects Queenstown with Wanaka via Cardrona. Though this is a more direct route than via Cromwell, and knocks about 50km off the journey it is by no means a short cut. The route is twisty and narrow in places and as the highest motoring road in New Zealand – passing the crown saddle at 1120m above sea level – it attracts plenty of snow and ice. It has great views over the Wakatipu Basin but during winter you'll definitely need to carry snow chains.

- ***Vulnerability to Earthquake***

  The effect of an earthquake of the transportation network is likely to cause widespread disruption across all mediums of transportation. Roads will be significantly damaged and blocked as mass movements will obstruct many arterial routes throughout the district. Queenstown airport is likely to be significantly damaged from liquefaction and the risk of seiche and tsunamis on the glacial lakes will restrict movement across the water. The entire transportation network is expected to be disrupted for at least the first few days. Progressively networks will become available first water transport, then rail system, then airport and finally roads. The roading network is the most vulnerable network and has the potential

  Roads may be severed by damaged or collapsed bridges. There may be localised damage on many streets caused by structural failure, collapse of underground and overhead services, damage from water mains or other forms of flooding such as seiches. Landslides and rockfalls will be abundant especially in areas like the Kawarau Gorge. Debris from buildings, poles bridges and other structures overhead wires and abandoned or crashed vehicles may also disrupt roads. Kerbs and channels and road surfaces would be distorted and broken. Damage to drainage, sewage and high pressure water mains will cause extensive damage to roads. Flooding, intense rain, or icy conditions following the earthquake could exacerbate the situation. Excavation of buried pipelines and cables to repair damage to telephone and power cables will also cause damage. The networks ability to function is highly dependant on the magnitude and location of the event and thus disruptions are difficult to predict. There are however areas in the district which are expected to be disrupted following an earthquake.

  Earthquake damage to bridges will vary greatly. Common damage to bridges designed within recent years (including the Lower Shotover Bridge and many of the smaller bridges that are spread throughout the area) will be controlled yielding of columns and joints. Although some repairs will be needed the bridges should remain usable by vehicles. Bridges built before the mid-1960's (including the Kawarau Bridge, Twin Bridge, Edith Cavell Bridge, Arthurs Point Bridge and the bridge near Albert Town) are expected to sustain considerable damage such as retaining walls, and batter slope failure, yielding, rotation, lateral movement and settlement. They are also likely to produce considerable amounts of debris and in some cases may collapse into the valley beneath them. Such damage will cause immense disruptions to the transportation network in and around the district isolating some communities until a temporary bridge is built. In some cases alternative routes will be available.

Transport on the lakes in the first few hours or days after the event may prove hazardous due to the occurrence of a seiche or tsunami. Any watercraft in the lakes at the time of the earthquake should be moved away from the shoreline immediately after the quake and into the open channels as this will reduce the impact of the large waves shoaling on the beaches.

Damage to runways, taxiways and aprons is likely to be negligible at Wanaka airport and easily repaired. The damage to Queenstown airport is likely to be more sustained as it is located on an area prone to liquefaction. It is expected that damage would be moderate to minor and that repairs will be limited to about 3 days. The large grass areas would still remain usable for light aircraft and military aircraft such as the Hercules. Most buildings, including the main passenger terminal are likely to remain usable despite suffering superficial damage such as cracks and broken windows. Underground services such as fuel storage, sewage and water supplies are likely to be damaged and special attention will be required at fuel depots to reduce the risk of fire. Equipment and machinery within buildings at the airport such as communication equipment, navigation and power distributors could be damaged.

- ***Vulnerability to Mass Movements***

  The effect of mass movements on the transportation network will cause localised disruption especially on the roads in and out of the district. Fortunately, there are a few alternative routes into and out of the district therefore if there is a major disruption of one route then an alternative route could then be used. There is no risk to airport facilities from mass movements. There is a small risk from mass movements causing tsunamis within the glacial lakes which could present a serious danger to any craft on the water.

- ***Vulnerability to Meteorological Hazards***

  The effect of meteorological hazards on the transportation network will cause widespread disruption. Strong winds can cause roads to be blocked by trees and overhead services, traffic signs and roofing, glass and other building debris. Abandoned and crashed vehicles, including trucks and trailers, could also disrupt roads. The main impact on the airports would be on the navigational and communication equipment as the aerials and masts will not have been designed to withstand these excessive wind gusts. The restoration of services after a windstorm could be achieved relatively quickly assuming the airport has spare aerials and mast components easily accessible. Wind blown debris will need to be cleared prior to operations recommencing.

Snow is not an uncommon sight for people in the Queenstown Lakes district, for at least 14 days out of the year snow is abundant in the district. However if a significant amount of snow were to fall over the district, say a snowstorm that may last several days of more, the transportation network will be seriously impacted. Roads may be completely blocked by snow and in some locations by trees and overhead power services. Abandoned and crashed vehicles may also add to the disruptions. If the snow freezes on road surfaces, traffic disruptions would increase markedly as the ice will not be cleared until the snow has thawed. All vehicles in these conditions would require chains if the roads are passable.

The spreading of grit would help alleviate icy conditions, however, if the snow falls faster than it was cleared then it wouldn't be worthwhile to grit/clear the roads and thus the roads will become impassable. Alternative routes may be possible in some areas. During times of heavy snow on the roads surfaces can be seriously damaged through the use of chains combined with grit that eats way at the roads causing potholes to develop.

Strong winds could make water transport extremely hazardous particularly for sail boats not only because the wind strongly affects how sail boats operate but because lakes in the district are large enough for waves to develop on the surface, making the water in the lakes as hazardous as storms out to sea.

The airport would be closed during periods of strong winds but could be immediately reopened after the storm has passed. The operations may have to be limited if the navigational aids have been damaged. Full restoration of airport services could take up to 3 weeks. Heavy rain may trigger mass movements that could seriously disrupt the transportation system.

The effect of snow on airport operations will depend on what happens after the snow falls and to some extent how "wet" the snow is when it falls (i.e. the amount of water in the snow when it is melted). If the snow freezes to the runway surfaces the airport will be closed until the snow thaws. Currently there are no acceptable methods available for clearing frozen snow/ice from runways.

During the snowfalls however the airport will be closed and efforts to clear the snow from the runways will begin immediately after the snowstorm ends. The ability of the airport maintenance staff to clear the snow is limited by equipment and although the main strip may be cleaned reasonably quickly, provided freezing hasn't occurred. The clearing of snow from around navigational equipment will be slow and manpower intensive.

- ***Vulnerability to Flooding***

  The effect of flooding on the transportation network will cause significant disruptions on the roads winding themselves around the glacial lakes. The road to Glenorchy and Kingston is likely to be cut off by the rising water levels of Lake Wakatipu and several streets within the Queenstown and Wanaka CBD's will be closed due to inundation. Flooding may also increase scouring of lake margins causing some road sections to wash out. Along with the physical disruption of the flood waters, it is likely that silt will be dumped upon the roads. Due to the nature of many of the catchments in the district it is unlikely that any of the bridges will be washed out due to the excess water draining from these catchments.

4.6.3 TRANSPORTATION MANAGEMENT

The transportation system in the Queenstown Lakes District is owned and maintained by several organisations. Transpower is ultimately responsible for the state highways in the area and contracts Works Infrastructure Ltd to maintain it. The local roading network is owned by the Queenstown Lakes District Council and is maintained by Imtech Ltd. Airports are also owned by the Queenstown Lakes District council.

Routine operation and maintenance times for the roading network are listed below however it is important to remember that these times correspond to a single failure and does not take into consideration, other repairs needed to the system or other systems within the district such as sewerage or water supply. These restoration times are only to be used as a rough guide only as Works Infrastructure and Imtech Ltd does not guarantee that repairs can be made within these time frames.

RESTORATION ACTIVITY	TIME TAKEN
Potholes	1 day to 1 week
Crack sealing	1 day to 1 month
Surface deformations	1 day to 1 month
Bridge repairs	1 day to 3 months
Jetty repairs	1 day to 3 months
Runway repairs	3 days to 4 months
Temporary bridge replacement	1 week to 1 month
Bridge construction	18 months to 2 years

- ***Management of an Earthquake Event***

  Bridge vulnerabilities could be reduced using typical mitigation measures such as strengthening connections, increasing column strength and ductility, strengthening retaining and approach structures and the strengthening of laterals. Where it has been identified that bridge collapse is likely, or if that structure is unstable, then all vehicles would be prevented from using the bridge until major repair/rebuilding is completed. This may last up to several months depending on the damage sustained by the bridge and the importance of the structure for recovery.

  Where moderate to severe damage is predicted and where temporary additional support is needed, vehicle restrictions will be put in place. These would be:

  - Immediately after the earthquake, emergency vehicles only, one vehicle at a time and crawl speed. This restriction would remain until temporary work is completed – typically in the order of a few weeks.
  - Following propping and/or other short term repairs the bridge could be restricted to normal highway traffic although speed and weight restrictions would probably apply. That is one vehicle at a time travelling about 30km/hr. This restriction would remain until more permanent repairs could be completed – typically in the order of several months.

  Where some damage is identified, but the bridge remains usable, the probable restriction would be a speed limit approximately 30km/hr until repairs are completed.

  Generally alternative routes would be available nearby possibly on a restricted speed width or loading basis. Bridge damage and blockages caused by mass movements may take considerable time to reinstate whereas roads subjected to liquefaction and other localised damage will be repairable relatively quickly albeit temporarily.

Reinstatement of the roading network will depend on the resources available, importance of a route and priorities. Extensive damage is expected over wide areas it could take several months for some routes to be temporarily reinstated and may take a number of years before the roading network is fully repaired and returned to normality. It must be noted that the transportation network is only one lifeline and the limited contracting, machinery and manpower will need to be shared in order to reinstate all lifelines.

- ***Management of a Mass Movement Event***

  In the event of a mass movement the council will be required to remove the excess material using bulldozers and other machinery. Consultation will need to be made with engineers and geologists and the road is likely to be blocked or reduced to a single lane while the road is cleared.

- ***Management of a Meteorological Event***

  Immediate response during meteorological hazards may be difficult as communications and overhead power lines may be damaged, thus preventing early responses to road clearance. Initial priorities however would focus on establishing emergency corridors for emergency services, rescue and movement or people.

- ***Management of a Flooding Event***

  In the event of a flood the components that are most vulnerable is the roading network that runs along the shoreline of the large glacial lakes. In many areas access will be cut off to outlying communities. Roads will need to be cordoned off until the flood waters subside.

CHAPTER FIVE
SCENARIO

5.1 INTRODUCTION

Scenarios are used in this study to better understand and help plan for the future. A successful scenario tells the story of a defined hazard and its specific impacts. It draws the reader in by incorporating familiar aspects of the community that can be readily recognisable. Decision makers are able to visualise specific impacts that are based on currently accepted scientific and engineering knowledge. A scenario improves awareness of the effects of a disaster to a community as a whole by bringing together information from a number of disciplines and taking advantage of the unique perspectives to describe a single catastrophic event.

The following diagram illustrates the basic logic used in this chapter:

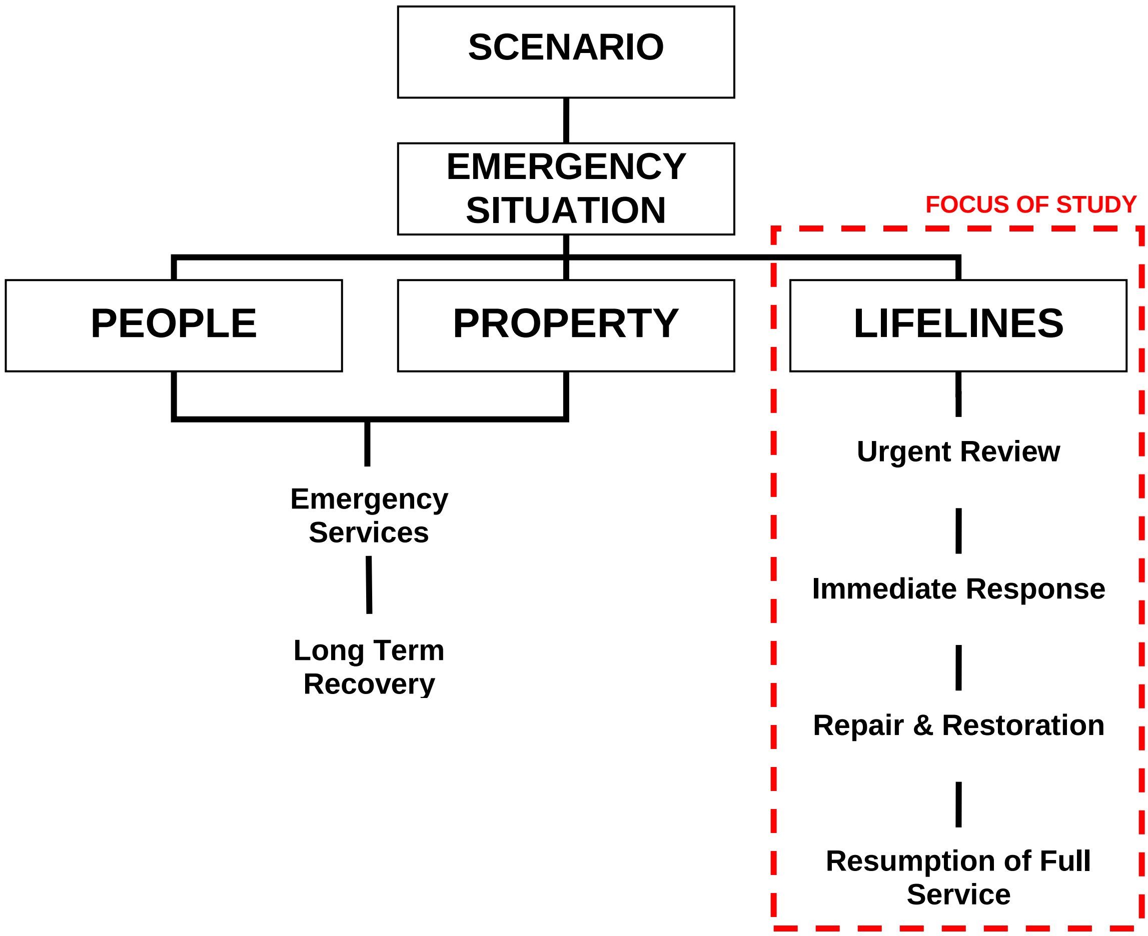


Figure 5.1: Flow diagram illustrating the basic logic used in this chapter.

Scenarios were created based upon current scientific understanding of each of the hazard and from lessons learnt in past disasters. Background information on hazards that was gathered as part of the hazards assessment is used to set the scene. The section then leads into the emergency situation by explaining why the scenario was chosen. A scenario is not in any way intended to predict what would actually happen. Rather, it gives a plausible and feasible picture of a possible major and widespread disaster simply to better illustrate the needs and priorities of the community.

The emergency situation was created from the information revealed from the lifeline vulnerability assessments. As this project is based around lifelines the focus is primarily based around the response and restoration of these essential services. People and property are acknowledged as being an important part of an emergency situation however; this is beyond the scope of this study.

Lifelines that require urgent review after a disaster are those that threaten life and property in the community. For example, damaged components of the electricity network have the potential to ignite fires. These components must be isolated before any other work begins on the network. Lifelines that require immediate response, are those lifelines with high interdependencies (i.e. those lifelines that require restoration before other lifelines can be restored) for example the transportation network. Repair and restoration of lifelines occurs once all urgent reviews and immediate responses have been carried out. This stage of the restoration process is generally the longest due to the number of failures involved. Resumption of full service and a sense of normality should follow (this may be years after the initial event.

5.2 EARTHQUAKE SCENARIO

There are many sources of earthquakes that threaten the Queenstown Lakes District. Within the district itself, several active and potentially active faults, have been identified. The Moonlight, Cardrona and Hawea faults are all identified as being active, as well as the Larkins and Shotover faults being potentially active. Faults off the south-western coast of the South Island, next to Fiordland also have the potential to severely shake the district. However, based on current research and historical patterns of significant earthquakes the most likely source of a major earthquake will be from the Alpine Fault.

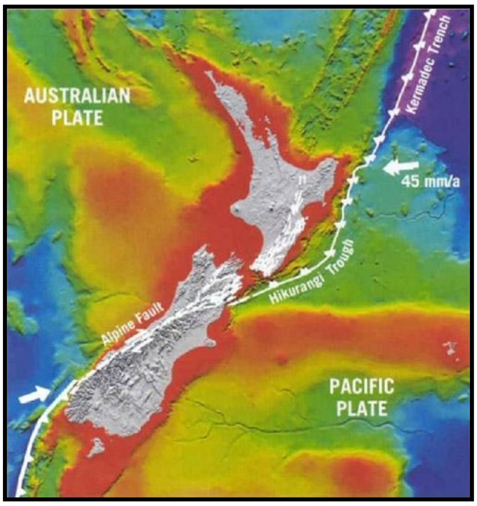


Figure 5.2: New Zealand Tectonic Setting

The Alpine Fault earthquake was chosen as the scenario for this study because of the high probability of it occurring within the near future and because of the threat it presents to communities within the Queenstown Lakes District. By its very nature, this scenario presents the worst-case and it is possible that the earthquake may be less severe than predicted. It is also possible that some of the consequences will be more severe than foreseen. However, it is not possible to define a more likely sequence of events than that provided.

The Alpine fault lies to the west of the Queenstown Lakes District, its nearest point being inland from Haast. Pressure along the alpine fault has been building for about 280 years since it was last released by a large earthquake in 1720 AD. Based upon the frequency at which large magnitude earthquakes occur along the alpine fault, every 100 – 300 years, the next earthquake is expected any day. As the time interval between ruptures increases, so does the stress in the overlying rocks, hence the greater the time interval, the greater the magnitude of earthquake. Scientists (Yetton et. al., 2000) have predicted that a future earthquake centred on the Alpine Fault will probably have a magnitude greater than 8, will last for at least two minutes, and be felt throughout the entire South Island of New Zealand and possibly as far away as Sydney, Australia.

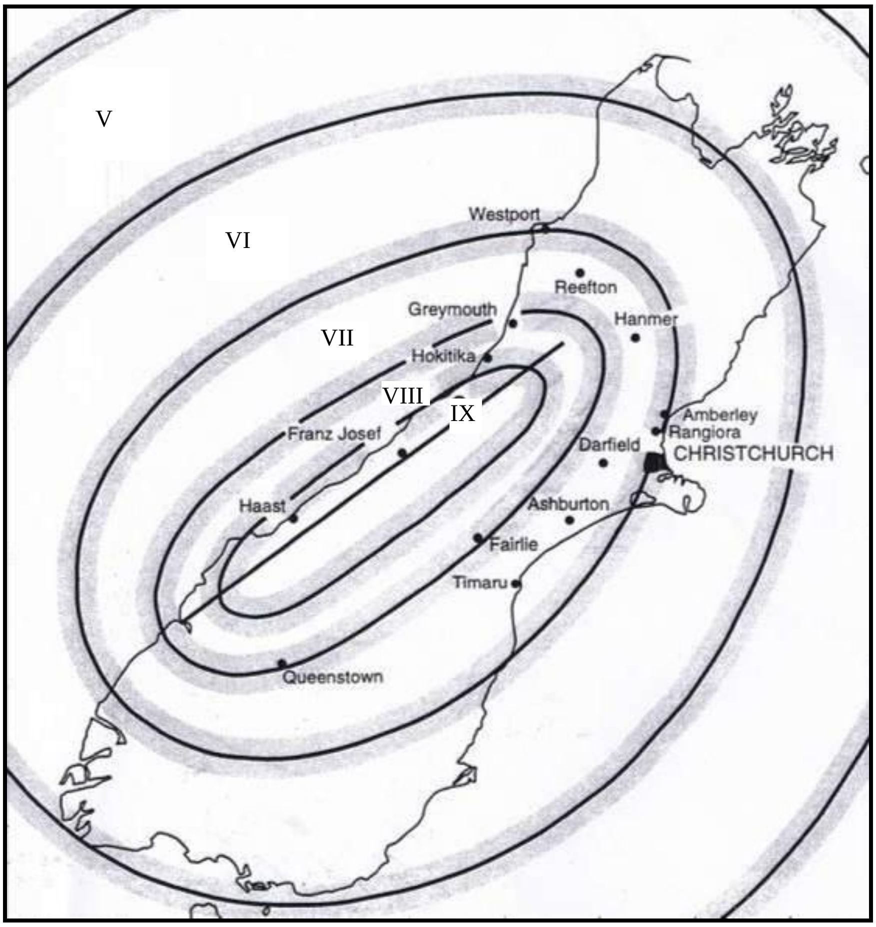


Figure 5.3 : Earthquake Intensity Map of the South Island using the modified Mercalli Scale (Yetton, 2000)

The Alpine Fault earthquake will almost certainly occur with no recognisable warning and it may be triggered by the rupture of another nearby fault; however we will only know this afterwards. Similarly, the Alpine Fault earthquake will alter the tectonic stress distribution around the region and other faults in the area may rupture in the days or years following it. The rupture length of the earthquake is likely to be up to 400km in length extending from Haast, north to Ahaura. The earthquake may occur as one continuous period of shaking or it may occur as a series of earthquakes as the fault ruptures along parts of its length.

Damaging aftershocks of up to magnitude 7.5 commence immediately after the quake, with multiple tremors occurring just within the first few hours. Aftershocks are likely to continue for several months after the main earthquake, decreasing in frequency and magnitude with time. Ground shaking intensity will be dependent on the geology, with more intense shaking occurring in low lying areas. Liquefaction and widespread ground damage will occur on land built up on alluvial fans

5.2.1 EMERGENCY SITUATION

In the Queenstown Lakes District shaking intensities of VIII to IX on the Modified Mercalli Scale can be expected. Shaking of this magnitude is capable of causing significant damage to structures and foundations. Electricity, telecommunications, water supply, wastewater removal and transportation networks may be all severely disrupted. Casualties are likely to be in the thousands, with hundreds requiring hospitalisation. The majority of casualties are likely to be adequately treated with basic first aid. A number of deaths should also be anticipated.

- ***Geological and Geomorphological Effects***

  The effects of the shaking will be amplified in areas of soft sediments such as on alluvial fans and other low-lying areas. These areas are also susceptible to liquefaction which may have severe consequences for infrastructure situated on the land. In the mountainous high country regions of the district, countless landslides of all sizes can be expected. Some landslides may create dams across rivers or streams. These landslide dams have the potential to cause breakout flash flooding.

  The increased sediment load in rivers resulting from the large volumes of landslide material entering the systems may cause high water turbidity, river aggradation and channel avulsion with implications for drinking water quality, and river control. Huge sediment and gravel deposits will have downstream effects for years. Areas such as the Shotover River may be radically transformed.

Shaking may also result in seiches (water waves generated by seismic oscillations) being generated on the lakes. Mass movements displacing water in the lakes are also capable of generating large waves. This creates an additional hazard to the communities located around the shoreline, particularly on lakes Wakatipu and Wanaka.

- ***Buildings***

  Significant building damage can be expected throughout the Queenstown Lakes District as a result of ground shaking. Buildings subjected to mass movement or liquefaction will be particularly vulnerable. From the effects of the 1994 Northridge earthquake we can expect that the buildings designed and constructed using modern (mid-1970's or later) seismic requirements will perform well structurally, but the buildings built before the 1970's can be expected to sustain significant structural damage. In the 1995 Kobe earthquake the main cause of the collapse was attributed to the weak lateral load resisting capacity in which the walls could not support the heavy roofs during severe ground shaking. An important lesson learned from the Northridge earthquake is that although some buildings may not sustain structural damage they still may be condemned as a result of chemical spills, fires, gas leaks, water damage, falling ceiling tiles and other non structural impacts. Buildings that have sustained significant damage may require immediate evacuation.

- ***Electricity Supply***

  Electricity supply maybe lost throughout the region for at least 48 hours after the event as a result of transmission and distribution failures. Resumption of the supply will be delayed due to poor access to damaged components. Full restoration of electricity supply may take from 1 week to 1 month after the event. In the 1994 Northridge earthquake several major high voltage substations located near the epicentre sustained serious damage due to the high levels of ground motion. Damage was sustained mainly by brittle component such as circuit switches and components made out of porcelain.

  As a result of these effects, substations through out New Zealand have been seismically strengthened; however some brittle components within the electricity system are indispensable. To mitigate the effects of this vulnerability, electricity network operators have ensured that there are sufficient replacement components available. Damage to components that are sourced from overseas will take 18 months to restore however the risk of damage is considered low.

- ***Telecommunication System***

  The land based telephone network will be completely useless after an earthquake, at least initially, due to either damage sustained to the network components, power loss or network congestion. The loss of electricity is likely to be the main cause communication disruption in most places. The Queenstown and Wanaka exchanges have back up generators which will require constant refuelling every 12 hours. In spite of this we should not be dependent on these back up systems working as back up systems can fail also (as discovered in the 1994 Northridge earthquake).

  The loss of the land-based telecommunication system together with the loss of many transportation routes will mean that some communities such as Cardrona and Makarora maybe completely cut off and isolated from the main centres. Isolated communities will need to manage almost on their own for some time (3 – 4 weeks) without significant outside assistance. People in the townships will need take up leadership and co-ordination roles and be responsible for providing rescue and first aid.

  The broadcast network (television, radio, satellite, and UHF and VHF communication) which is likely to arise unscathed from an alpine fault earthquake will be the main means of communication between people and communities.

  Telecommunications are likely to be re-established to most communities in the district within 2 weeks. However, these may continue to be unreliable for some time due to reduced capacity, aftershocks and landslides. Full restoration of the telecommunication network is expected from 2 weeks to 1 month after the event.

- ***Water Supply***

  After a major earthquake such as an Alpine Fault earthquake, affected water supply systems are likely to have no power to drive pumps. The only pump stations in the Queenstown Lakes District that have back up generators are the intakes at Wakatipu and Wanaka. However due to the damage sustained to the rest of the network (e.g. mass movements damaging reservoirs, liquefaction and ground movement destroying distribution pipelines) these are unlikely to achieve nothing more than extracting water from the lake.

  Due to the increase sediment loads in the rivers as well as the risk of sewerage contamination, water sourced from rivers and lakes in the district will need to be boiled. Groundwater supplies should be unaffected in terms of water quality. The water supply system is likely to be out of operation for up to several months or more after the quake. Turbidity in the lakes and rivers affecting water quality will also continue for some time after the earthquake and people will need to boil water for several months.

- ***Wastewater***

  The wastewater system is likely to be severely damaged during an Alpine Fault earthquake. Much of the damage will be sustained by the pipelines due to severe ground shaking, land displacements and liquefaction. Pipelines that cross bridges will be particularly vulnerable. Some oxidation ponds may experience ground settlement and slumping of pond walls but should remain operational.

  The impact of the damage sustained to the stormwater system should be minimal as long as heavy rain doesn't fall in the weeks following the earthquake. Restoration of this infrastructure will not be a priority unless life and property are in danger. Full restoration of this service will take years. Meanwhile, communities will have to rely of ground soakage for all the stormwater draining needs.

  The impact of the damage sustained to the sewerage system however will be more disastrous. Sewage removal will be severely disrupted for months after the earthquake due to the damage sustained to the pipelines. Fortunately, most sewage will be effectively contained within underground pipelines until service is restored. There may however be situations where sewage is discharged into the streets creating a significant health hazard requiring immediate attention. It is anticipated that where necessary and possible, individuals will have to arrange their own toilet facilities e.g. pit latrines. Normal levels of service are expected to be reinstated in 6 to 12 months. Rain exacerbates sewer damage causing isolated pockets of sewage flow on the ground surface.

- ***Transportation***

  Most roads in the region are effectively closed due to landslides and rockfalls, destruction of bridges and damage to the road surface. Many rivers and streams will become impassable. The major towns will be isolated for at least the first week but more than likely will be months before any road transport will be able to reach them. The smaller communities will be isolated for months. Direct road access to Canterbury through the Lewis Pass is not restored until at least 16 days to 3 months after the earthquake. Road access over the Haast Pass is expected to be re-established after 3 to 6 months. Road access from the south to Kingston should be restored within a few days to a week after the event, and although access through to Queenstown may be still severely disrupted, due to mass movements across the highway, transportation across Lake Wakatipu could provide the crucial link to the districts survival. Fuel shortage would be a concern.

As a precautionary measure airports and bridges will be closed to allow for inspection. Queenstown airport is situated in an area susceptible to liquefaction and therefore may sustain severe damage forcing it to close and therefore completely isolating the Queenstown area. It is likely that if Queenstown airport closes it will be out of operation for at least the first week after the earthquake. Airport operations will therefore run out of Wanaka airport where the damage is expected to be minimal to non-existent, due to its location. After the earthquake the Queenstown and Wanaka airports are likely to become the main routes for getting expertise and urgent supplies into the Queenstown Lakes District, and for getting the severely injured out for medical assistance. It is likely that air access to isolated areas around the district will be very important particularly for evacuating tourists as road access to these areas is unlikely to be open for months.

Wharfs and jetties on the glacial lakes may suffer some damage due to ground settlement. However, these glacial lakes may provide a key transport link for distributing supplies. Temporary structures may therefore be built in the days or weeks following the earthquake. Railway authorities state that rail re-instatement can be faster than for roads. Therefore there could be an option to reinstate the line into Kingston in order to ship in supplies if necessary.

- ***Emergency Services***

  A sudden onset national Civil Defence emergency of long duration will be called. It is to be expected that medical services and other Civil Defence emergency services will be overwhelmed and severely inhibited in their rescue efforts by the scale of damage to roads and buildings. Overseas rescue and medical assistance will be required. However, an event of this magnitude will affect the entire South Island of New Zealand and therefore it should be expected that other cities such as Christchurch may require more assistance than other areas. However, assistance will be prioritised by the NCMC in Wellington. Co-ordination, information, and leadership will be the three highest needs required of, and by Civil Defence.

  Provision of trained personnel will be the foremost greatest vulnerability to the emergency services. Because of the nature of the earthquake and the quality of buildings, a relatively small number of people will be killed. However, a large number of people will suffer disabling injuries putting added pressure on emergency services and hospitals. Provision of emergency medical facilities for many major trauma victims will be difficult and will last for 3-4 weeks after the event. The Queenstown Lakes District Hospital and secondary facilities such as the sports area are all located in an area susceptible to liquefaction, therefore if any of these facilities are severely damaged, the pressure on emergency services will be dramatically increased. Fire, Police and Ambulance services should all still be operational in the event of an Alpine Fault Earthquake

5.2.2 EMERGENCY RESPONSE

The following list is a general description of responses that will need to be undertaken during a disaster. The list has bee written in order of priority; however, some tasks can be undertaken simultaneously. It is important to note that these response procedures should only be used as a general strategy as there are multiple factors that can influence management decisions.

LIFELINE	GENERAL DUTIES	EARTHQUAKE SPECIFIC TASKS
ELECTRICITY	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the electricity system Identification & management of other damaged components	Components likely to be damaged as a result of an earthquake include transmission lines, distribution lines. Transmission network owned by Transpower NZ Ltd may be able to be assessed remotely, however a visual inspection will be required to determine resources required for restoration
TELE-COMMUNICATION	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are	Components likely to be damaged as a result of an earthquake include fibre optic transmission lines, copper cabling distribution system, some communication masts/towers

	causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the telecommunication system Identification & management of other damaged components	If electricity is disrupted to the Queenstown and Wanaka exchanges electricity generators will require constant refuelling
WATER SUPPLY	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the water supply system Identification & management of other damaged components	Components likely to be damaged as a result of an earthquake include water distribution networks and some reservoirs. Depending on the damage to the water supply network, measures may need to be employed to conserve water. (e.g. rationing, filling of miscellaneous storage tanks).
WASTEWATER	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the wastewater system Identification & management of other damaged components	Components likely to be damages as a result of an earthquake include sewage reticulation network. Sewage that has spilled into the environment or onto streets will require containment & cleaning up
TRANSPORTATION	Identification & management of disruption to the roading network	Components likely to be damaged as a result of an earthquake include some

	that is hindering emergency response. Identification & management of disruption to airports Identification & management of disruption to water transport Identification & management of disruption to the roading network	bridges and Queenstown Airport. Structural engineers will be required to assess the strength of bridges in the district. Queenstown airport is susceptible to liquefaction. Restoration of this system component is considered to be a priority The roading network may be severely disrupted from the occurrence of mass movements.

EMERGENCY SERVICE	GENERAL DUTIES	EARRTHQUAKE SPECIFIC TASKS
CIVIL DEFENCE (QLDC)	Arrange community welfare, support facilities and services Receive, assess and disseminate information for response agencies Ensure communications are in place with key response agencies Provide information to the media and the public about the event and the response	A state of emergency will need to be declared so that civil defence and emergency services can employ special powers. Ground based reconnaissance and Airborne reconnaissance (preferably helicopters) The following areas are important to recon: ▪ Urban areas ▪ Valleys to assess landslide dam formation ▪ Roading network particularly state highways ▪ Walking tracks Specialist advisors may be needed to assess slope stability and landslide dam formation Set up emergency operation centres and gather intelligence of the situation from responders. Start an incident board so that intelligence is accurately recorded and efficiently used. Organise reconnaissance teams to assess the damage and identify priorities that will need to be addressed.

		Community sector posts will need to be established by the designated wardens and information communicated back to the EOC. Information will need to be broadcast to the public detailing the extent of the damage and providing practical advice. Provision of food and supplies. This will need to be coordinated as it will need to be done primarily using aircraft.
POLICE	Maintain Law and Order Take all measure within their power to protect life and property Take all measure within their power and authority to facilitate the movement of rescue, medical, fire and other essential services Control access into and out of a disaster/evacuated/ hazardous area. Assist the coroner by identifying the dead and notifying next of kin. Assist in the registration of evacuees and the location of missing persons Ensure the security of the EOC, Hospitals, emergency medical units.	Assist with the evacuation of people at risk from secondary hazards such as large waves on the lakes or imminent mass movements events Control access across damaged bridges. This may require completely blocking traffic Ensure strict management of incoming persons to the district Assist with the evacuation of tourists from the district as this will free up resources within the district such as accommodation in hotels/motels etc
FIRE SERVICE	Control, contain and extinguish fires Contain hazardous substance releases and spillages	Prevent, control, contain and extinguish fires within urban areas. Fire fighters will need to assess the functionality of the water supply system so that they can manage water efficiently. This may involve using innovative methods to preserve water in reservoirs,

	Rescue trapped persons from fire or other emergencies Establish specialist fire protection at aircraft/helicopter landing sites Assist in the transmission of public warnings Re distribute water for specific needs	such as extracting water directly from lakes, swimming pools etc.
ST JOHN AMBULANCE	Triage, treatment, transport and care of those injured. Determination of the priorities and eventual destination of those injured	
HOSPITALS	Triage, treatment and accommodate those severely injured	

5.2.3 TRANSPORTATION MANAGEMENT

People trapped on roads and tracks, or in accommodation will need to be looked after where they are for days due to road blockages from landslides, airport damage, and limited means of transportation. If the earthquake were to occur during the winter months there could be added disruption to the transportation network though snow/ ice on the roads.

The Queenstown Lakes District is totally reliant on the roading network to provide arterial access throughout the region. Even with concentrated repair resources, susceptible major highways can still be inaccessible for over a month, therefore tourists and other travellers are likely to be stranded. Any ski-fields that were operating will pose severe rescue difficulties.

Other than the vulnerability from mass movements the roading network is particularly vulnerable as a result of the damage that bridges may have sustained Examples of such bridges are the Edith Lovell bridge on the road the connects Queenstown and Arrowtown and the twin bridges that provide the main access in the Queenstown region from Cromwell. The modern highway bridge that crosses the lower Shotover River just before reaching

Frankton is expected to withstand the effects of an earthquake. Some bridges also provide support for water supply and sewerage pipe work, and electricity and communication cables. After a major earthquake, road access to CDEM co-ordination centres and key facilities such as the airport, critical communication infrastructure and medical centres will be a high priority. These will be followed by access between the satellite towns of Kingston, Glenorchy, Arrowtown, Arthurs Point Cardrona and Makarora. Other forms of transport, possibly boat, but more likely aircraft, are likely to play an important role during the initial response period. Road access will also be required to important utilities such as communication and power infrastructure and water supply systems to get them functioning.

Transportation networks will need to be reinstated; Queenstown Airport will be a priority but the road network will also need to be cleared urgently. Repairs to the airport and the roads will involve heavy machinery (e.g. excavators). Fortunately due to the high levels of development in the district there should be an abundance of machinery. The priorities of which routes to clear first will be dependent on the situation but primary routes are likely to include SH6 from Queenstown down through Kingston to provide access into the district (this route is likely to be the fastest to clear). The road to Arrowtown that runs alongside Lake Hayes, the Crown Range Road to provide access to Wanaka and finally the rest of SH6 that runs through Cromwell. Repair of this highway however is likely to take 6 – 12 months. Route priority will be based upon how fast routes will be reinstated when considering the damage sustained by the bridges. The two major bridges that are likely to be damaged beyond repair in the district are the Edith Lovell Bridge near Arthurs Point and the Twin Bridge that crosses the Kawarau River in the Gibbston Valley.

Transportation disruption creates a complex situation for emergency response the transportation system is considered to be the most important lifeline system. In the Queenstown Lakes District much of the transportation system will be disrupted, therefore alternative arrangements must be considered. For example, Queenstown is likely to be completely isolated with mass movements blocking road access and liquefaction damaging the airport. Alternative transport options for getting supplies into the district may include:

- Fly-in supplies to Wanaka airport then transport them by truck over the Crown Range Road
- Fly-in supplies to Invercargill airport then transport them by truck north to Kingston. Supplies can then be shipped across Lake Wakatipu to Queenstown.
- Fly-in supplies to Cromwell airport

5.2.4 INDIVIDUAL RESPONSE

In an earthquake, the general public should follow these guidelines as indicated below

- ***Before an Earthquake***

  Preparing for an earthquake will help reduce damage to homes and business and assist survival. Individuals should:

  - Develop a Household Emergency Plan and prepare an Emergency Survival Kit to manage being isolated for up to two or three weeks
  - Identify safe places within homes, schools or workplaces. A safe place is under a strong table (remember to hold on to the legs) or underneath an interior doorway (remember to hold the door to prevent it swinging). It is important that you seek refuge somewhere close to you, no more than a few steps, or two meters away. This will avoid injury from flying debris.
  - Check household insurance policies for cover and amount
  - Seek qualified advice to make sure houses are secured to its foundations. Also check that any renovations comply with the NZ Building Code
  - Heavy items such as furniture should be secured to the floor or wall.
  - Share scenarios with others. Talking about surviving and coping an earthquake will help each person to adequately prepare.

- ***During an Earthquake***
  - If inside a building, move to a safe place
  - If outside, move no more than a few steps, then drop, cover and hold
  - If driving, pull over and stop
  - If near the beach or shoreline, drop, cover and hold then move to higher ground immediately in case a seiche or tsunami follows the quake

- ***After An Earthquake***
  - Expect to feel aftershocks
  - Help those nearby
  - If in a damaged building, try to get outside and find a safe, open place
  - Do not go sightseeing to look at the damage the earthquake has caused
  - If there is a gas smell, turn off the gas main outside the building if it is safe to do so
  - If there are sparks, broken wires or evidence of electrical system damage, electricity at the main fuse box should be turned off if it is safe to do so
  - If property is damaged, take notes and photographs for insurance purposes

- Listen to the radio for information and advice
- If able to help and it is safe to do so then go to a community sector post to see if you can assist.

While each Sector Post has been designated a warden it must be highly stressed that arriving at a sector post in search of help should be done as last resort. If possible, stay with friends or relatives as some sector posts may be unable to cope with the influx of people.

5.3 LANDSLIDE SCENARIO

A Landslide is the downslope movement of rocks under the influence of gravity. Due to the geology of the rock that underlies much of the Queenstown Lakes District a landslide event has a high probability of occurring. Landslides in the district have been reasonably frequent in the past with the last movement occurring in 1999 during the “big floods”. Fortunately, this event occurred in a region that was not highly populated however it does illustrate the risks that a landslide may have on a hillside development.

Landslides generally occur after a long period of intense rain where the overlying soil has been highly saturated. Earthquakes also have the potential of triggering landslides. If an earthquake occurs when the ground is highly saturated the chance of a landslide occurring is greatly increased. Most of the developments in the Queenstown Lakes District have been built using modern engineering standards that evaluates the suitability of the ground before it is built upon. This includes investigations into land instability. Although buildings and houses are built using all these precautions, landslides can be somewhat unpredictable. Anything located on a landslide will be severely destroyed regardless of building strength.

A landslide that occurs along part of the Frankton Arm was chosen as the scenario on the basis of past movements, the risk it presents to lifelines and the potential for housing developments to be affected. Although mass movements occur more frequently elsewhere (e.g. rockfalls in the Kawarau Gorge) in the district they do not pose the same amount of threat to lifelines and therefore were not chosen as the scenario.

5.3.1 EMERGENCY SITUATION

The Frankton landslide scenario may or may not occur with warning. If there is a warning it will be in the form of new cracks or bulges on the ground, road or footpath, and leaning trees, retaining walls or fences. More subtle indications of an impending landslide may include doors and windows sticking, gaps in building frames or exterior cladding and waterlogged ground in areas that are not usually wet. Most landslides that occurred in Queenstown's past occurred suddenly, without warning.

Anything located on or in the path of a landslide will most likely be totally destroyed or severely damaged. This includes all buildings and structures, lifelines such as roads, water and wastewater pipelines, and telecommunication and electricity networks both overhead and underground.

- ***Electricity System***

  There are three transmission lines that supply Queenstown with electricity. Two of the lines run along SH6a on Frankton Arm and the third goes along the Shotover River through Arthurs Point. A major landslide along Frankton Arm is likely to disrupt the supply of electricity to the Queenstown substation. However the effect of this disruption should be minimal as long as the third transmission line from Arthurs point remains undisturbed. Electricity supply to most of the residents along Frankton Hill we be disconnected due to the landslide.

- ***Telecommunication System***

  A fibre optic line that connects Frankton to Queenstown runs along the length of Frankton arm. If a landslide were to occur in its vicinity it would likely to severe this connection. Fortunately there is another fibre optic link being installed from the south and therefore once this line becomes operational will provide redundancy to the system meaning that the impact to the telecommunications network will be minimal.

- ***Water Supply***

  Water supply to the residents along Frankton Arm will be affected however due to the redundancy built into the system the effects to the rest of the community should be minimal. Rupture of the water main that runs along Frankton Arm may cause additional movement due to the added pressure of excess water. Breakages on the water main should be restored within days after the event, as was the case in the 1999 Frankton landslide.

- ***Wastewater System***

  The effects to the stormwater system will be similar to the effects sustained to the rest of the system in that it will be totally destroyed. However this system in this location is not of vital importance and therefore will not affect the community greatly. However caution needs to be taken to make sure that water drainage is properly managed around the landslide site otherwise further movement may occur.

  Any component of the sewage system that intersects the landslide slip surface area will be significantly damaged. The most likely component that will be severed during a landslide along Frankton will be the sewage main that runs along the Frankton walkway that carries most of the Queenstown's untreated waste to the bonds at the lower Shotover River. In the 1999 Frankton landslide that is exactly what happened. Temporary repairs on the pipe were completed as best as possible within hours of the event from the pipes that could be salvaged. However, leakage still occurred into Lake Wakatipu for some days until more permanent repairs could take place.

- ***Transportation***

  Road access to Queenstown is likely to be disrupted in the event of a landslide however; Queenstown may still be accessed by Malaghan Road via Arthurs Point. This detour will add approximately 20 minutes to the drive which may have implications for emergency services; otherwise the effect on the transportation network should be minimal. As landslide material is progressively cleared access may be achieved for single lane traffic

- ***Emergency Services***

  In the event of a landslide, a state of local emergency will be declared in order to give the police the power to control the affected area and enable them to evacuate residents that could be at risk from future movement. A helicopter will be used to fly geologists and the Civil Defence Officer over the area to evaluate the nature of the earthquake and identify other areas that will need to be evacuated in case of further movement. In the 1999 Frankton landslide over 30 houses and apartments were evacuated and Frankton Road was closed so the slip area was cordoned off to restrict entry.

  The declaration of Local Civil Defence emergency may last for more than three weeks. Regular meetings will be required over the duration of the emergency to update residents on the movement of the slip and the effect on houses. In the months that follow a landslide residents will be able to return to their homes at different stages. In the 1999 landslide there were still a number of evacuated residents waiting to return to their homes, five months after the initial event.

5.3.2 EMERGENCY RESPONSE

The following list is a general description of responses that will need to be undertaken during a disaster. The list has bee written in order of priority; however, some tasks can be undertaken simultaneously. It is important to note that these response procedures should only be used as a general strategy as there are multiple factors that can influence management decisions.

LIFELINE	GENERAL DUTIES	LANDSLIDE SPECIFIC TASKS
ELECTRICITY	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the electricity system Identification & management of other damaged components	Components likely to be damaged as a result of a landslide include distribution lines and the low voltage network. Any components affected by the slip will need to be isolated and may need to be turned off until it is safe to repair damaged components.
TELE-COMMUNICATION	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the telecommunication system	Components likely to be damaged as a result of an earthquake include fibre optic transmission lines, copper cabling distribution system, some communication masts/towers If electricity is disrupted to the Queenstown and Wanaka exchanges electricity generators will require constant refuelling

	Identification & management of other damaged components	
WATER SUPPLY	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the water supply system Identification & management of other damaged components	Components likely to be damaged as a result of an earthquake include water distribution networks and some reservoirs. Depending on the damage to the water supply network, measures may need to be employed to conserve water. (e.g. rationing, filling of miscellaneous storage tanks).
WASTEWATER	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the wastewater system Identification & management of other damaged components	Components likely to be damages as a result of an earthquake include sewage reticulation network. Sewage that has spilled into the environment or onto streets will require containment & cleaning up
TRANSPORTATION	Identification & management of disruption to the roading network that is hindering emergency response. Identification & management of disruption to airports Identification & management of disruption to water transport	Components likely to be damaged as a result of an earthquake include some bridges and Queenstown Airport. Structural engineers will be required to assess the strength of bridges in the district. Queenstown airport is susceptible to liquefaction. Restoration of this system

	Identification & management of disruption to the roading network	component is considered to be a priority The roading network may be severely disrupted from the occurrence of mass movements.

EMERGENCY SERVICE	GENERAL DUTIES	LANDSLIDE SPECIFIC TASKS
CIVIL DEFENCE (QLDC)	Arrange community welfare, support facilities and services Receive, assess and disseminate information for response agencies Ensure communications are in place with key response agencies Provide information to the media and the public about the event and the response	A state of emergency will need to be declared so that civil defence and emergency services can employ special powers. The primary area affected by the slip will need to be evacuated. Generally, depending on the nature of the landslide evacuees will be asked to leave immediately Helicopter should be used to fly specialists over the area so that they can evaluate the nature of the landslide and whether other resident need to be evacuated. All other potential areas at risk will need to be evacuated. Generally depending on the nature of the landslide, evacuees will have thirty minutes to gather belongings until they have to leave. Evacuees will be asked to go to friends or relatives places. A civil defence community post will have to be established if there are evacuees with no-where to go. Longer term accommodation may be provided by local motels/hotels. Geologists and engineers will need to survey the area in order to determine safety and accessibility. Remedial stabilisation work may also need to be

		undertaken before people start entering the area. Permanent stabilisation work may need to be started to even out the slope. This may require demolition of buildings and re-routing of essential services. The lines of communication between engineers, geologists and contractors must remain open and clear throughout this process Clear communication will also need to be made to home owners to inform them of the situation. This may be done through regular meetings. Owners that are not aware of the situation (i.e. on holiday) will need to be informed by the council before any work begins involving their property. Once stabilisation work has finished it will be important to continue monitoring the slip particularly during heavy rainfalls to ensure that the slope does not deteriorate. Once the slip has been monitored through a heavy rainfall and after geologists have deemed the slope stable people will be able to return to their homes
POLICE	Maintain Law and Order Take all measure within their power to protect life and property Take all measure within their power and authority to facilitate the movement of rescue, medical, fire and other essential services Control access into and out of a disaster/evacuated/ hazardous	Cordon off affected area and control the movement of emergency services and evacuees Assist with the evacuation of people at risk from further movement. Assist with the control of movement of people returning to their homes to salvage personal items. Depending on the nature of the landslide families will be allowed back into their homes for 30

	area. Assist the coroner by identifying the dead and notifying next of kin. Assist in the registration of evacuees and the location of missing persons Ensure the security of the EOC, Hospitals, emergency medical units.	minutes each, one at a time to retrieve essential possessions. Some people may not be allowed back into their homes and police will have the responsibility to ensure they don't
FIRE SERVICE	Control, contain and extinguish fires Contain hazardous substance releases and spillages Rescue trapped persons from fire or other emergencies Establish specialist fire protection at aircraft/helicopter landing sites Assist in the transmission of public warnings Re distribute water for specific needs	Assist with the rescue of trapped persons and the evacuation of survivors. Assist with efforts to extract probable bodies from the area
ST JOHN AMBULANCE	Triage, treatment, transport and care of those injured. Determination of the priorities and eventual destination of those injured	
HOSPITALS	Triage, treatment and accommodate those severely injured	

5.3.3 INDIVIDUAL RESPONSE

In a landslide, the general public should follow these guidelines as indicated below

- ***Before an Landslide***

Getting ready before a landslide will help reduce damage to homes and businesses and assist in survival.

- Find out from the council if there have been landslides in the area before and where they might occur again
- Check for signs that the ground may be moving. These signs include:
- Sticking doors and window frames
- Gaps where frames are not fitting properly
- Decks and verandahs moving or tilting away from the rest of the house
- New cracks or bulges on the ground, road or footpath
- Leaning trees, retaining walls or fences
- Water springs, seeps or waterlogged ground in areas that are not usually wet

- ***If You Think A Landslide Is About To Happen***
  - Individuals will need to know how to respond immediately:
  - Take the Getaway Kit and evacuate.
  - Contact the local Civil Defense Emergency Management Office
  - Warn neighbours who might be affected

- ***After A Landslide***
  - Do not return to a site that has been affected by a landslide until it has been properly inspected
  - Take photographs and notes for insurance purposes when it is safe to do so.

5.4 STORM SCENARIO

Severe weather that brings with it heavy rain and strong winds will most likely be attributed to a low pressure weather system moving slowly over the district. Although relatively rare when compared with the rest of the country, this is because these types of storms generally lose intensity before they reach the Queenstown Lakes District and the area itself is relatively sheltered from the weather due to the blocking effect of the Southern Alps. Generally storms in the district just comprise of heavy rain which causes the rivers and glacial lakes to rise to the point that they overflow. Alternatively storms consist of strong winds that are funnelled through the mountain ranges, capable of destroying infrastructure due to flying debris. They infrequently consist of both strong winds and heavy rain as storms (tropical cyclones) generally lose intensity as they travel south.

This somewhat hypothetical 'perfect' storm that consists of strong winds and heavy rains was chosen in order to intensify the effects of a meteorological hazard. Although these storms have occurred very rarely in the past their occurrence in the future should not be questioned particularly when global warming is having such a vast influence on the weather.

5.4.1 EMERGENCY SITUATION

The perfect storm will occur with a warning from the Met Service a couple of days in advance. The storm will begin by gale force winds hitting the area, initially from the northwest, but then from the southwest as the associated weather system passes over the area. Nor' westerly winds can reach mean wind speeds above 50 knots (93km/h), gusts may exceed 80 knots (148km/h). This will be enough force to uproot small trees, some big branches may be twisted or snapped off, roofs may be torn away (particularly tiled roofs) and garden sheds destroyed. These gusts will make driving hazardous, particularly for high-sided vehicles and motorbikes. Strong winds in the region will last between six and twelve hours.

As the wind begins to abate heavy rain begins to fall over the region rapidly increasing the levels of the rivers. Sustained heavy rainfall may last for six to twelve hours creating a risk to communities beside the flood prone lakes and dampening response effort to the strong winds that battered the area earlier.

- ***Buildings***

  There will be no significant structural damage to buildings within the area. In a worst case scenario some buildings may lose their roofs, some garden sheds may be destroyed and any structures attached loosely to a building such as a chimney stack may be damaged.

- ***Electricity***

  Electricity supply will be lost throughout the region for at least 48 hours after the event as a result of transmission and distribution failure due to flashovers or damage caused by flying debris. Resumption of the supply will be delayed due to poor access to damaged components and safety fears. Full restoration of electricity supply may take from one week to one month after the event depending on how quickly repairs can be made to the system.

- ***Telecommunication System***

  The telecommunication system will remain largely intact during a storm. The only components that may be damaged are the household aerials and satellite dishes. Cell towers and broadcast aerials have been designed to withstand the effects of strong winds of up to 200 km/hr.

- ***Water Supply***

  Water supply should remain largely unaffected by the occurrence of a storm; however boil water notices may be distributed due to the possibility of winds causing turbidity within the lakes.

- ***Wastewater***

  Stormwater systems may become overwhelmed with excess water causing localised flooding particularly in low lying areas and areas located alongside rivers and streams. Flooding may cause damage to property and disruption to the transportation network. The sewerage system will remain unaffected in the event of a storm.

- ***Transportation***

  Strong winds can cause roads to be blocked by trees and overhead services, traffic signs and roofing, glass and other building debris. Abandoned and crashed vehicles, including trucks and trailers, could also disrupt roads. The main impact on the airports would be on the navigational and communication equipment as the aerials and masts will not have been designed to withstand these excessive wind gusts.

  The airport would be closed during periods of strong winds but could be immediately reopened after the storm has passed. The operations may have to be limited if the navigational aids have been damaged. Full restoration of airport services could take up to three weeks. Heavy rain may trigger mass movements that could seriously disrupt the transportation system.

- ***Emergency Services***

  The Fire Service would be busy assisting with flooded basements and houses in low-lying areas as priorities allowed. Police would cope, but would become more heavily involved in road closures and diversions. Civil Defence Emergency Operations Centres would be fully activated throughout the region.

5.4.2 EMERGENCY RESPONSE

The following list is a general description of responses that will need to be undertaken during a disaster. The list has bee written in order of priority; however, some tasks can be undertaken simultaneously. It is important to note that these response procedures should only be used as a general strategy as there are multiple factors that can influence management decisions.

LIFELINE	GENERAL DUTIES	STORM SPECIFIC TASKS
ELECTRICITY	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the electricity system Identification & management of other damaged components	
TELE-COMMUNICATION	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the telecommunication system Identification & management of other damaged components	Components likely to be damaged as a result of an earthquake some communication masts/towers
WATER SUPPLY	Identification & management of damaged components that are threatening life and/or property	Water quality in the lakes will need to be monitored as storms can increase turbidity.

	Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the water supply system Identification & management of other damaged components	
WASTEWATER	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the wastewater system Identification & management of other damaged components	
TRANSPORTATION	Identification & management of disruption to the roading network that is hindering emergency response. Identification & management of disruption to airports Identification & management of disruption to water transport Identification & management of disruption to the roading network	Airports are likely to be closed until the storm dissipates The roading network may be severely disrupted due to debris material blocking access

EMERGENCY SERVICE	GENERAL DUTIES	STORM SPECIFIC TASKS
CIVIL DEFENCE (QLDC)	Arrange community welfare, support facilities and services Receive, assess and disseminate information for response agencies Ensure communications are in place with key response agencies Provide information to the media and the public about the event and the response	A state of emergency will need to be declared so that civil defence and emergency services can employ special powers. Council will need to monitor the level of the lakes just in case heavy rain forces the water level in the lakes to rise
POLICE	Maintain Law and Order Take all measure within their power to protect life and property Take all measure within their power and authority to facilitate the movement of rescue, medical, fire and other essential services Control access into and out of a disaster/evacuated/ hazardous area. Assist the coroner by identifying the dead and notifying next of kin. Assist in the registration of evacuees and the location of missing persons Ensure the security of the EOC, Hospitals, emergency medical units.	

FIRE SERVICE	Control, contain and extinguish fires Contain hazardous substance releases and spillages Rescue trapped persons from fire or other emergencies Establish specialist fire protection at aircraft/helicopter landing sites Assist in the transmission of public warnings Re distribute water for specific needs	Responsible for installing temporary roofs. Help clear debris material
ST JOHN AMBULANCE	Triage, treatment, transport and care of those injured. Determination of the priorities and eventual destination of those injured	
HOSPITALS	Triage, treatment and accommodate those severely injured	

5.4.3 INDIVIDUAL RESPONSE

In a storm, the general public should follow these guidelines as indicated below

- ***Before a Storm***

  Getting ready before a storm will help reduce damage to homes and businesses and assist in survival.

  - Develop a Household Emergency Plan and prepare an Emergency Survival Kit to manage being isolated for up to two or three weeks
  - Check the that the roof and guttering is secure every two years
  - Keep materials at hand for repairing windows, such as tarpaulins, boards and duct tape

- If renovating or building, make sure all work complies with the New Zealand building code which has specific standards to minimise storm damage

- ***When A Warning Is Issued***
  - Pick up any debris in the area that could become airborne
  - Bring rubbish bins indoors
  - Bring pets inside. Move stock to shelter
  - Listen to the local radio station for information

- ***During A Storm***
  - Open windows on the side of the building away from the wind. This will relieve pressure on the roof and help prevent it lifting
  - Close all curtains to slow down flying glass and airborne objects
  - Stay away from doors and windows. If the wind becomes destructive, shelter further inside the house
  - Don't walk around outside. Don't drive unless absolutely necessary

- ***After A Storm***
  - Contact the local council and insurance company if the building has been severely damaged
  - Ask the council for advice on how to clean up debris safely

5.5 FLOODING SCENARIO

Flooding is an integral part of the natural environment in the Queenstown Lakes District. Since early European settlement in the 1850s significant floods in the Queenstown Lakes District have occurred on five separate occasions. This has been beneficial as some people in the district have become accustomed to the threat of flooding so that when it occurs again it will not come as a surprise. However there are people in the district who are still unaware of the full extent of the hazard.

The flooding hazard in the district results from when a slow moving front brings periods of sustained heavy rainfall over the catchment areas in the Southern Alps. This is generally accentuated during spring where the winter snow adds to the accumulated amount of water flowing down the rivers. It is important to note that it doesn’t have to be raining in the district itself for the river and lake levels to rise.

The first sign of an impeding flood is generally given by the heavy rain warnings issued by the New Zealand Meteorological Service. Heavy rain warnings are issued when more than 50mm of rain is expected within the following 6 hours. This heavy rain has the potential to cause floods on rivers and the lakes. The most frequent type of flooding in the Queenstown Lakes District, and hence the basis for this scenario, occurs when the lake levels rise above their maximum and overflow into the streets of the lakeside communities. Flooding of the glacial lakes has the potential to affect numerous communities located on the lake edge.

Flooding of the glacial lakes was chosen as the scenario because of the high probability of it occurring within the near future and because of the threat it presents to communities within the Queenstown Lakes District. By its very nature, this scenario presents the worst-case and it is possible that the flooding may be less severe than predicted. It is also possible that some of the consequences will be more severe than foreseen. However, it is not possible to define a more likely sequence of events than that provided.

5.5.1 EMERGENCY SITUATION

The glacial lakes flooding scenario will begin by the New Zealand Meteorological service issuing a special weather bulletin report forecasting that enough rain would fall over the area to significantly raise the level of the lakes in the Queenstown Lake District. This weather bulletin is likely to be announced a day or two before the lakes actually begin to respond. For example during the 1999 Queenstown floods the special weather bulletin was issued on the Sunday, and late on Monday the lakes began to respond by rising 4cm each hour. By 10:00pm Tuesday night the water in the lakes started spilling into the streets of the Queenstown CBD.

The Queenstown Lakes District Council in cooperation with the Otago Regional Council monitors the levels of the lakes. There are two predetermined trigger levels at which responses are carried out. When the lake reaches the first trigger level (Lake Wakatipu: 310.80m & Lake Wanaka: 279.70m) the CBD residents and businesses will receive a flood warning. At this point they are encouraged to implement their individual flood management plans. Council contractors will place staff on standby and begin preparations to counter the effects of flooding (such as sandbagging). If the lake reaches this level, it does not mean there is a flood. It is an opportunity to warn people about the hazard. The second trigger point (Lake Wakatipu 311.25m, Lake Wanaka 280.20m) is used to inform people that the flood is imminent and they should take action immediately. This is the point that sand bagging and other responses are started. The timing between the two trigger levels are variable and can be anywhere between hours to days depending on how much rain is dumped over the area.

In the early stages of flooding sandbagging is useful to protect buildings against early intrusion. However once the water has risen over 10-20cm, sandbagging does not stop water intrusion but becomes a very useful protection against wave action and debris build-up. Because of the large surface areas of the lakes the water will rise uniformly and steadily.

As seen in 1924, damage generated by high lake levels can be exacerbated by exposure to wind-generated waves. The long fetch (approximately 20 km) and significant depths of Lake Wakatipu, even within Queenstown Bay force the waves to break and run up within the CBD. This may potentially cause damage over and above that arising from inundation due to high lake levels.

As long as there are no more substantial rainfalls in the days following the event the lakes will start to drain away. Again because of the large surface area of the lakes the water will fall slowly and steadily. In the 1999 floods it took 12 days before the water drained away. For this scenario we can expect the flood waters to linger around for at least 15 days.

Once the floodwaters recede, the task of cleaning up the contaminated mud left behind will begin. In the 1999 flooding event there was great haste to clean up and dry out businesses in Queenstown, therefore blowing heaters were transported to Queenstown from Auckland to speed up the drying process. Flood waters contain large quantities of sediment that settle out after the flood has gone and the costs of removing this sand and silt can be high. The flood also leaves behind a mass of rotting vegetation and other biologicals that constitute a severe health risk to the population. Houses and buildings damaged by the flood may have to be demolished or extensively repaired. People may also be affected psychologically by the event.

The 1999 flooding event also highlighted the fact that disasters don’t always occur independently from one another. For example during the 1999 floods a number of roads were affected by mass movements. Roads that were affected by slips over the duration of the crises included state highway 6 at a number of locations state highway 6A between Frankton and Queenstown Cadrona Road, Glenorchy Road, Crown Range Road and a number of other roads. Also an environmental hazard occurred when fuel tanks located at the Queenstown water taxis site ruptured. To manage this spill an eight metre exclusion zone was placed around the spill as volunteers worked to control it. The leakage of the tanks took up time and resources at a stage where the floods were at a high level and resources were precious.

- ***Buildings***

  Flooding will leave the Queenstown and Wanaka CBD covered with mud, plastering floors, walls, doors and shelves and anything located below the water level which can rise above 2m. Carpet will be sodden, floorboards wet and a terrible smell will likely be left behind by the mud and sewage. Anything below the level of the flood will have to be thrown away and replaced including carpet, electrical fittings, skirting boards and any food; canned or not.

  Damage will be enhanced due to the extended period of time that the buildings will be inundated. For example structural damage will result from timber studs warping and splitting. Both Wanaka and Queenstown will become a serious health risk due to decomposing food, waste from sewage lines and waste from grease traps contaminating the flood waters. Areas will have to be cordoned off and information on the situation disseminated to the public. People will be advised to stay away from the stagnant floodwaters lapping against buildings in marine parade, the mall and beach street.

  In 1999 flooding affected about 5 hectares of the Queenstown Township with most businesses being badly affected. Some businesses were still flooded up to two weeks after the water had peaked and some were still out of operation and continuing refurbishment more than three months after the initial event. In addition, a number of individual properties in Queenstown were also affected by a breakout flood from Brewery Creek.

- ***Electricity Supply***

  The electricity supply to the areas of the CBD in both Wanaka and Queenstown will be shut off for the duration of the flood. However because most of the area will be evacuated anyway and that essential infrastructure such as sewerage pumps stations has back up generators, the effects of the loss of power will be minimal. In the 1999 flooding event, in Queenstown, several transformers were switched off and more were partially submerged but were just able to be kept in service. If wave action had occurred, it would have been necessary to shut these transformers down as well.

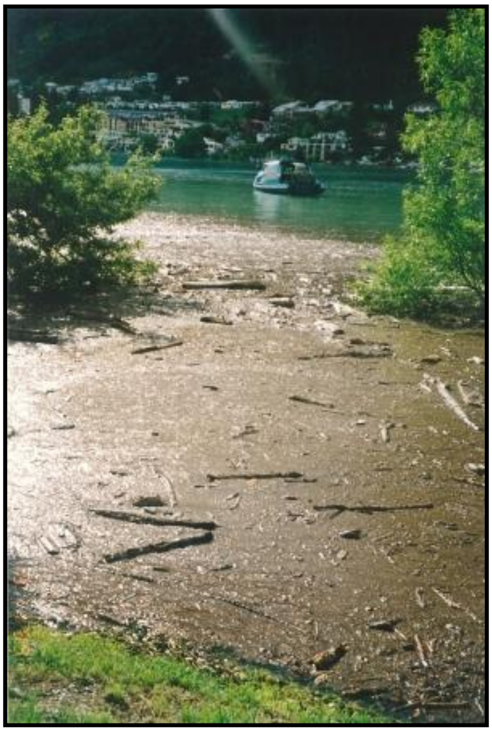
- ***Telecommunication System***

The telecommunication system within the inundated area will also fail for the duration of the flood. However, as the area will be evacuated and the fact that no critical components (such as the exchange) will be affected, the impact will be minimal. In the 1999 floods the landline communication to Wanaka failed due to phone overloading and this wasn't restored for three days.

- ***Water Supply System***

  By the time the water supply was re connected, the source of the water in Lake Wakatipu had become turbid and residents were advised to boil drinking water as a precaution until the following January three months after the event. Although this was notified via the free weekly newspaper, some people stopped boiling before the recommended time. There was a potential health risk from contaminated water supplies, arising from broken water supply and sewer pipes.

Figure 5.4: Effect of the 1999 Flooding event in Queenstown After sewage contaminated the lakes



- ***Wastewater System***

  Queenstown and Wanaka sewage systems will be overwhelmed with the in flow of lake water through grease traps, gulley traps, urinals and toilet pans. Key sewage pump stations that are located on the shoreline are likely to be kept in operation due to the flood mitigation options that have been employed. However, if the ingress of excess water is too much for the pumps to handle, the pumps will fail and sewage is likely to overflow the wetwell and contaminate the floodwaters, thus creating a significant health hazard.

- ***Transportation***

  The roading network around the lakes may be severely disrupted either due to landslips blocking the roads or inundation making roads impassable. Disruption of the roading network around the lakes may completely isolate communities such as Glenorchy and Kinloch

5.5.2 EMERGENCY RESPONSE

The following list is a general description of responses that will need to be undertaken during a disaster. The list has bee written in order of priority; however, some tasks can be undertaken simultaneously. It is important to note that these response procedures should only be used as a general strategy as there are multiple factors that can influence management decisions.

LIFELINE	GENERAL DUTIES	STORM SPECIFIC TASKS
ELECTRICITY	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the electricity system Identification & management of other damaged components	Components likely to be damaged as a result of flooding include the low voltage distribution netwok.
TELE-COMMUNICATION	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the telecommunication system Identification & management of other damaged components	Components likely to be damaged as a result of flooding include the copper cabling distribution system
WATER SUPPLY	Identification & management of damaged components that are threatening life and/or property Identification & management of	Water quality in the lakes will need to be monitored as flooding can produce adverse effects

	damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the water supply system Identification & management of other damaged components	
WASTEWATER	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the wastewater system Identification & management of other damaged components	Components likely to be damaged as a result of flooding include pump stations
TRANSPORTATION	Identification & management of disruption to the roading network that is hindering emergency response. Identification & management of disruption to airports Identification & management of disruption to water transport Identification & management of disruption to the roading network	The roading network may be severely disrupted due to inundation

EMERGENCY SERVICE	GENERAL DUTIES	STORM SPECIFIC TASKS
CIVIL DEFENCE (QLDC)	Arrange community welfare, support facilities and services Receive, assess and disseminate information for	A state of emergency will need to be declared so that civil defence and emergency services can employ special powers At the time that the Met Service issues a

	response agencies Ensure communications are in place with key response agencies Provide information to the media and the public about the event and the response	severe weather warning with a risk that water level in the lakes may rise above their maximum limits. The glacier lakes and the river capacities will need to be constantly monitored. This will be the responsibility of the Otago Regional Council. Once the water levels reach the first trigger point business owners and residents within the floodable margins will need to be notified of the flood warning and they need to implement their individual flood management plans. Once the water levels reach the second trigger point concluding that flooding in the district is immanent. Remedial works to reduce the effect of the flooding will be started. This will include sandbagging, the erection of chicken wire fencing along the lake front reserve to capture wave borne debris and to reduce the potential effects of wind generated waves a weighted oil boom and concrete blocks should be placed along the bay. Personnel to install these measures will be comprised of district and regional council staff, utility contractors and volunteers.
POLICE	Maintain Law and Order Take all measure within their power to protect life and property Take all measure within their power and authority to facilitate the movement of rescue, medical, fire and other essential services Control access into and out of a disaster/evacuated/ hazardous area.	Responsible for restricting access into parts of the town that have been inundated and ensuring warnings are a haired to

	Assist the coroner by identifying the dead and notifying next of kin. Assist in the registration of evacuees and the location of missing persons Ensure the security of the EOC, Hospitals, emergency medical units.	
FIRE SERVICE	Control, contain and extinguish fires Contain hazardous substance releases and spillages Rescue trapped persons from fire or other emergencies Establish specialist fire protection at aircraft/helicopter landing sites Assist in the transmission of public warnings Re distribute water for specific needs	Responsible for pumping out excess water from inundated buildings
ST JOHN AMBULANCE	Triage, treatment, transport and care of those injured. Determination of the priorities and eventual destination of those injured	
HOSPITALS	Triage, treatment and accommodate those severely injured	

5.5.3 INDIVIDUAL RESPONSE

In a flood, the general public should follow the guidelines as indicated below

- ***Before a Flood***

  Getting ready before a flood strikes will help reduce damage to homes and businesses and assist in survival.

  - Develop a Household Emergency Plan and prepare an Emergency Survival Kit to manage being isolated for up to two or three weeks
  - Find out if your home or business is at risk from flooding. If there is a risk, the local council can provide information to help you reduce the effects. This information includes advice on evacuation, how to protect homes and businesses and how to reduce the risk of flooding in the future.
  - Identifying the closest high ground is and how to get there
  - Keeping your insurance up to date

- ***When a Flood Threatens***
  - Listen to the local radio station for information and follow the advice and instructions from Civil Defence Emergency Management
  - Warnings will be announced from the local council.
  - If a property is about to be flooded furniture and other valuables can be moved to higher floors to keep them dry; doors, windows and other openings can be blocked to keep water out; emergency supplies of food and water can be prepared and emergency equipment such as warm, waterproof clothing can be readied.

- ***During a Flood***
  - Move out of the flooded area or go to the nearest high ground
  - Lift household items as high above the floor as possible
  - Do not attempt to drive or walk through floodwaters unless it is absolutely essential
  - Do not go sightseeing to look at the damage the flood has caused

- ***After a Flood***
  - Houses and buildings should be inspected and the damage assessed

CHAPTER SIX
DISCUSSION AND REVIEW

6.1 EMERGENCY RESPONSE

Emergency response is concerned with the:

- Preservation of life and safety
- Maintenance of Law and Order
- Care of the sick and injured
- Protection of property
- Inspection of damage
- Maintenance and restoration of essential services.

The principle functions during the response phase of a disaster are to:

- Co-ordinate the response of local emergency agencies within the district to ensure that efficient action is taken
- Arrange and co-ordinate logistics
- Arrange geotechnical or specialist services
- Arrange for community welfare and support facilities and services.
- Monitor events and escalate response as required
- Ensure emergency response agencies keep the EOC well informed
- Receive, assess and disseminate information for emergency response
- Ensure communications are in place with key emergency agencies
- Provide information to the media about the event and the response
- Ensure recovery preparation and implementation

The local controller with the assistance of a civil defence advisory group will be responsible for establishing priorities for emergency actions, figuring out the most effective use of available resources and for ensuring a timely response to emergency situations. The civil defence advisory group is comprised of council staff, contractors, specialist advisors and volunteers appointed by the council. The local controller and the Civil Defence advisory group also have the initial responsibility of disaster recovery until the decision is made to transfer responsibility to the disaster recovery manager.

The main role of the disaster recovery manager is to provide a co-ordinating focus for all the different agencies that will be involved in the recovery of the community. The recovery manager needs to be able to facilitate and give direction to all of the agencies involved with the recovery process The recovery manager is also responsible for ensuring that community views are gained and taken into account during the process. The disaster recovery manager will be responsible for the co-ordination of all disaster recovery activities in the Queenstown Lakes District

6.2 DISASTER RECOVERY

Disaster recovery is concerned with:

- Minimising the escalation of the consequences of disaster.
- Rehabilitating the emotional, social and physical well being of individuals within communities
- Taking the opportunities to adapt to meet the physical, environmental, economic and psychological future needs.
- Reducing future exposure to hazards and their associated risks.

The principle functions during the recovery phase of a disaster are to:

- Ensure the safety and health of people (with respect to recovery, this is generally the continuation of emergency welfare measures, public health and sanitation)
- Restore infrastructure and reinstate lifelines
- Assist with recovery issues such as housing, transport, food and water and psychological needs.
- Co-ordinate inspections of houses to assess requirements for re-occupation or repairs/replacement of damaged buildings.
- Assess of the needs of the community affected by the emergency
- Co-ordinate resources made available to the community
- Develop new measures to reduce hazards and risks.
- Determine and prioritise major areas that require recovery assistance
- Formulate recovery policies and strategies
- Establish a time frame for recovery actions
- Ensure co-ordination of recovery between agencies
- Assess and obtain recovery resources
- Monitoring recovery activities

Depending on the nature of the emergency the disaster recovery phase may range from days to months with some measures possibly continuing for years. The overall aim of disaster recovery in the Queenstown Lakes District is to return to a sense of normality with as little delay as possible

6.3 LIFELINE OPERATORS

Lifeline operators are responsible for reinstating lifelines in the event of a disaster or other unforeseen situation. Similarly to other agencies these organisations will have limited supplies and resources and are also likely to be vastly overloaded with work. The main vulnerability associated with lifeline operators will be due to personnel shortages and sourcing of spare parts. There are a number of factors that lifeline operators have also got to consider when responding to a disaster some of these include the health and safety of contractors, shifts and rosters of workers, psychological affects and how to efficiently co-ordinate responses.

In the event of a disaster on call lifeline contractors will need to identify priorities that they need to respond to immediately and while the lifeline liaisons make their way to the local emergency operation centre these priorities will need to be addressed. These priorities are likely to include tasks such as turning off some services (e.g. electricity, gas) and isolating damaged components (e.g. broken water and sewerage mains). Lifeline operators generally use the same principles when responding to a disaster as they do an everyday event.

Engineers, geologists and other professionals should make their way to the Civil Defence Emergency Operation Centre for briefing and deployment. Priorities for assessment include bridges, airports, dams, key buildings (EOC, Hospital, Sector Posts etc) houses and other structures.

Lifeline operators will need to call in off duty contractors. This will be done through normal channels. However this may prove difficult if telecommunication systems are non-functional. Having emergency response procedures in place before a disaster will ensure that when a disaster occurs off duty personnel know that they will be required and should meet at a designated location.

As contractors try to reach their specific designation points they should note down what they see along the way. Then, when they are briefed on the situation, critical information can be relayed to the local emergency operation centre.

6.4 LOCAL COMPANIES/ORGANISATIONS

Local companies and organisations in the Queenstown Lakes District have a responsibility to assess there own vulnerabilities and response procedures with respect to disaster management. Some companies may have more responses than others. Most businesses within the Queenstown Lakes District are developed around the industry of tourism and therefore many of them work with large groups of people, effectively making them as important as lifeline operators. For example businesses such as the skyline gondola and tourism ventures such as Skippers Canyon tours should have a disaster specific vulnerability plan that is associated to their own business. For example the skyline gondola has procedures in place for the evacuation of gondola cars. Information like that compiled within a single review will provide a basis for comprehensive emergency management procedures.

Tourism creates a complex situation for disaster management as the majority of people that come into the Queenstown lakes district live out of town. Hotels and motels should therefore have information about the hazards that threaten the Queenstown Lakes District so that visitors are aware of what will be involved in the management of these hazards, thus reducing their vulnerability to them.

CHAPTER SEVEN
SUMMARY AND CONCLUSIONS

7.1 PROJECT OBJECTIVES

The overall objectives of the Queenstown Lakes District Lifelines Project were:

- To identify hazards within the Queenstown Lakes District and to discuss the processes involved in their development.
- To study the risks posed to lifelines (water, power, sewerage, transportation and communication networks and emergency services) servicing the Queenstown Lakes District from various hazards.
- To recognise interdependencies, identify strategies and determine priorities for reducing the impact and restoration time of lifelines following such events.
- To create a scenario-based plan that will give a clearer understanding of where the key risk areas are, what services can be expected to fail during different disasters and what recovery times can be expected.
- To communicate these issues to those involved in the management of these services and to raise public awareness of their importance.

7.2 PROJECT METHODOLOGY

Project objectives were achieved by applying principles developed for other lifelines projects and integrating them all into one comprehensive review. The difference between this thesis and other reports is that this thesis has been designed to be relevant for both council and scientific community as well as the general public. In the appendix of this thesis is a wide range of background material that when strategically placed within the main text, results in a comprehensive disaster management review of hazards and lifelines in the Queenstown Lakes District.

This thesis also explores the principles of disaster management and emergency response with the aim that it will aid in the efficient management of the next natural disaster that threatens the Queenstown Lakes District. This thesis is no way intended to replace any material currently used in the discipline of emergency management but should be used to supplement it. The purpose of this thesis is to hopefully build a scenario not previously conceived by the reader so they can better prepare and respond to a disaster in the future.

7.3 KEY VULNERABILITIES AND INTERDEPENDACIES

The following section discusses the key vulnerabilities to lifelines in the Queenstown Lakes District. The areas of Frankton and Frankton Arm are particularly vulnerable as Frankton is located in an area that is prone to liquefaction and lifeline components situated within this area are likely to be severely damaged. Frankton Arm is also particularly vulnerable as it contains multiple services including water and sewage pipelines, electricity distribution lines as well as the main road into the Queenstown CBD.

- The main vulnerability of the electricity network are the transmission lines into the district that transverse Kawarau Gorge and the Clutha Valley. The two areas are particularly vulnerable to landslips and rockfalls and although transmission towers have been situated in areas suggested by geologists and engineers there is still a moderate risk of collapse.
- The telecommunication network is particularly vulnerable to flooding as when components become inundated the catastrophically fail and although the major components, such as telephone exchanges, are not at risk from rising lake levels. The do become vulnerable if a seiche or tsunami is created on either Lake Wakatipu or Lake Wanaka.
- The main vulnerability to the water supply and wastewater systems are the distribution components where they will be severely damaged during an earthquake making these services untenable. The water supply reservoirs are vulnerable to landslips creating a complex water management situation.
- Sewerage pump stations are particularly vulnerable to flooding, however many of these components have now been installed with a range of mitigation measures and as long as these measures work as designed the impact should remain minimal however if they are compromised this will become a particular hazard
- The transportation system particularly the roading network has a high vulnerability during an earthquake with most routes expected to be blocked or impassable. In the event of an Earthquake it is likely that the Queenstown Lakes District will become completely isolated
- Emergency services are likely to be vastly overwhelmed during any emergency. A classic example is the vulnerability assessed at the Queenstown Lakes District Hospital where one hospital with one doctor looks after the entire district population of around 60,000. Lakes district hospital is large enough to fit about 40 patient at one time.

Throughout the report reference is made to the fact that lifelines are dependant on other lifelines. Indeed no lifeline service can function totally independently and an assessment of the level of interdependence was carried out. The effects of interdependence can have a critical impact on recovery times. When considering the interdependence of all lifelines, including fire, ambulance and police, the dependence of all services on each other was assessed to be (from greatest dependence to least dependence):

- Transportation
- Fuels
- Communication
- Electricity Supply
- Buildings and structures
- Water supply
- Sewerage
- Stormwater

7.4 RESPONSE PRIORITIES

There is likely, for each situation, to be a "stack" of activities to be done in order of priority, including but not limited to rescue, power, water supply, road access, phone, radio etc. The order of the stack, and its components, will be different for different situations; and for any one location, it will change with time. The changing nature and order of priorities must be borne in mind as they could easily be forgotten in the stress of disaster response.

The following table summarises key tasks that will need to be addresses during disastrous situations and the agencies responsible for carrying them out:

TASK	Lead Agency	Support Agency
Impact Assessment and Reconnaissance	Police	• Civil Defence • Fire
Emergency Operations (Pre-declaration)	Police	• Civil Defence • Fire • Ambulance • Utility Liaisons • Council
Emergency Operations (During Declared Emergency)	Civil Defence	• Police • Fire • Ambulance • Utility Liaisons • Council
Warnings & Public Information	Police	• Civil Defence
Evacuations	Police	• Civil Defence

		• Fire • Ambulance
Law and Order	Police	• Private Security Firms
Care of Deceased	Police	• Hospital
Perimeter Control	Police	• Fire • Civil Defence • Private Security Firms
Pre-Hospital Emergency Care & Casualty Transport	Ambulance	• Fire • Civil Defence • Health Centres
Fire Fighting	Fire	• NZ Fire Service • Rural Fire Service • Airport Fire Service
Urban Search & Rescue	Fire	• Police SAR • Civil Defence • Ambulance
Hazardous Substance	Fire	• Police • Ambulance • Council • Hospitals
Electricity	Varies depending on situation	• Transpower • Aurora • Delta Utility Services • Contractors
Transport	Police	• Civil Defence • **Transit New Zealand** • **Works** • **Council** • Ambulance • Contractors • Engineers
Communications	Varies depending on situation	• Police • Fire • Ambulance • Civil Defence • Amateur Radio • **Telecom** • **DownerEDi Engineering** • Contractors
Water Supply	Delta Utility Services	• QLDC • Contractors • Public health
Wastewater	Delta Utility Services	• QLDC • Contractors • Public Health
Emergency Shelter	Police	• Civil Defence • Accommodation Providers
Welfare • **Food** • **Clothing** • **Registration** • **Personal Services**	Police (pre-declaration), Civil Defence (during emergency)	• Civil Defence • Police • Vets • SPCA • Other Relevant Organisations (e.g. insurance companies)
Volunteer Co-ordination	Civil Defence	• Police

7.5 LIFELINE LESSONS

Damaged lifelines can affect the lives and livelihood of thousands of people as well as impede emergency response and hinder post-disaster recovery. Following a major disaster the need for safe, effective and timely restoration of lifeline systems is critical. Improved co-ordination and prioritisation can accelerate recovery and reduce secondary hazards to life and property both immediately following a disaster and during the recovery afterwards.

Emergency management staff, that are involved in the response and recovery of a disaster should have lists of available resources that may be utilised in the event of a disaster. For example there should be lists associated to where they can find earth moving equipment. There should be other lists that identify where fuel reserve are kept, other lists will have contact details for engineers, geologists and other advisors. The more lists that emergency management agencies compile the easier the response and recovery phases, will be to manage

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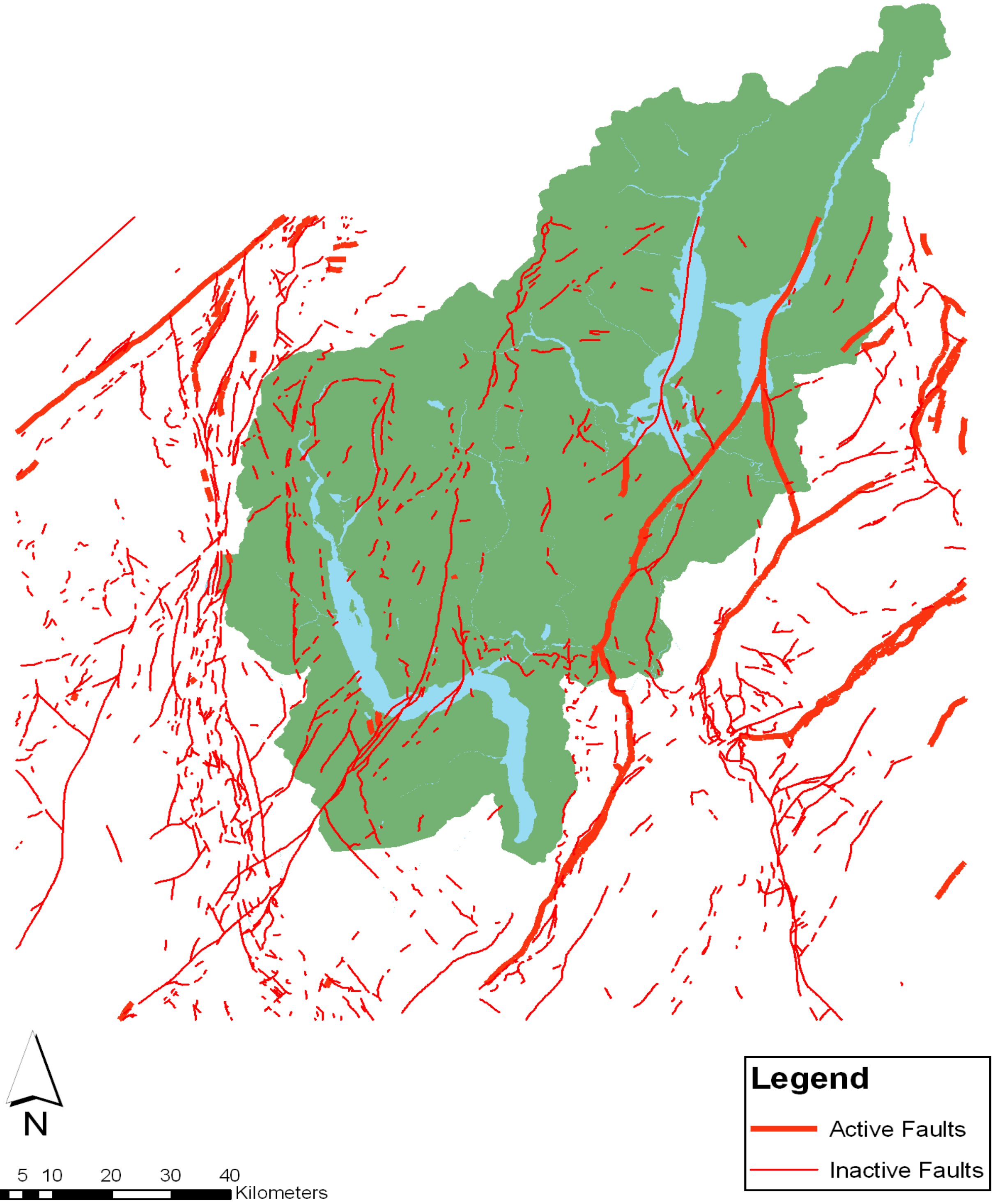
MAPS

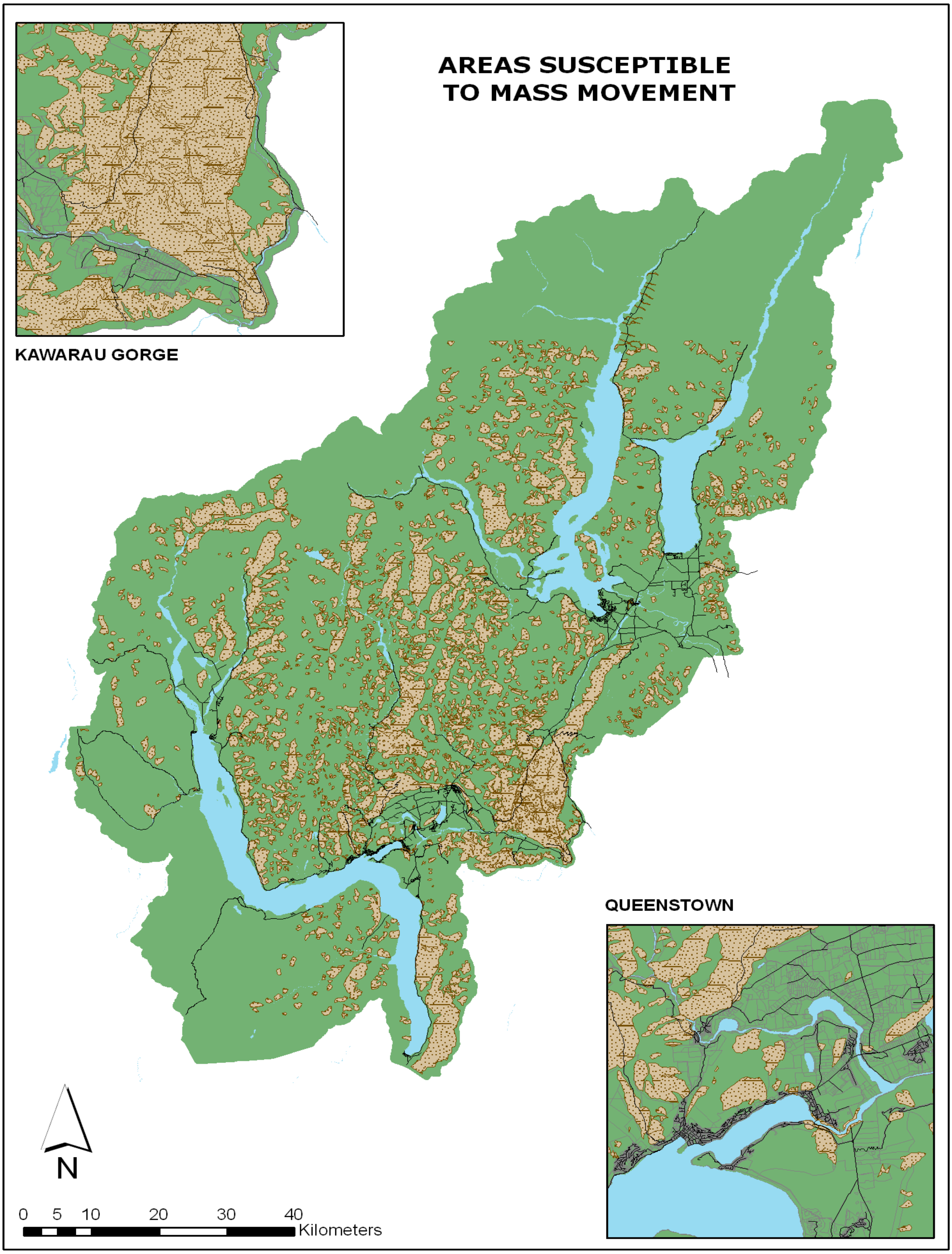
MAP ONE:	**Earthquake Hazard Map – Location of Faults**
MAP TWO:	**Earthquake Hazard Map – Areas Susceptible to Liquefaction**
MAP THREE:	**Mass Movement Hazard Map – Areas Susceptible to Mass Movements**
MAP FOUR:	**Flooding Hazard Map – Queenstown**
MAP FIVE:	**Flooding Hazard Map – Wanaka**
MAP SIX:	**Flooding Hazard Map – Glenorchy and Kingston**
MAP SEVEN:	**Electricity Network**
MAP EIGHT:	**Telephone Network**
MAP NINE:	**Water Supply Network – Queenstown**
MAP TEN:	**Water Supply Network – Wanaka**
MAP ELEVEN:	**Wastewater Network – Queenstown**
MAP TWELEVE:	**Wastewater Network – Wanaka**

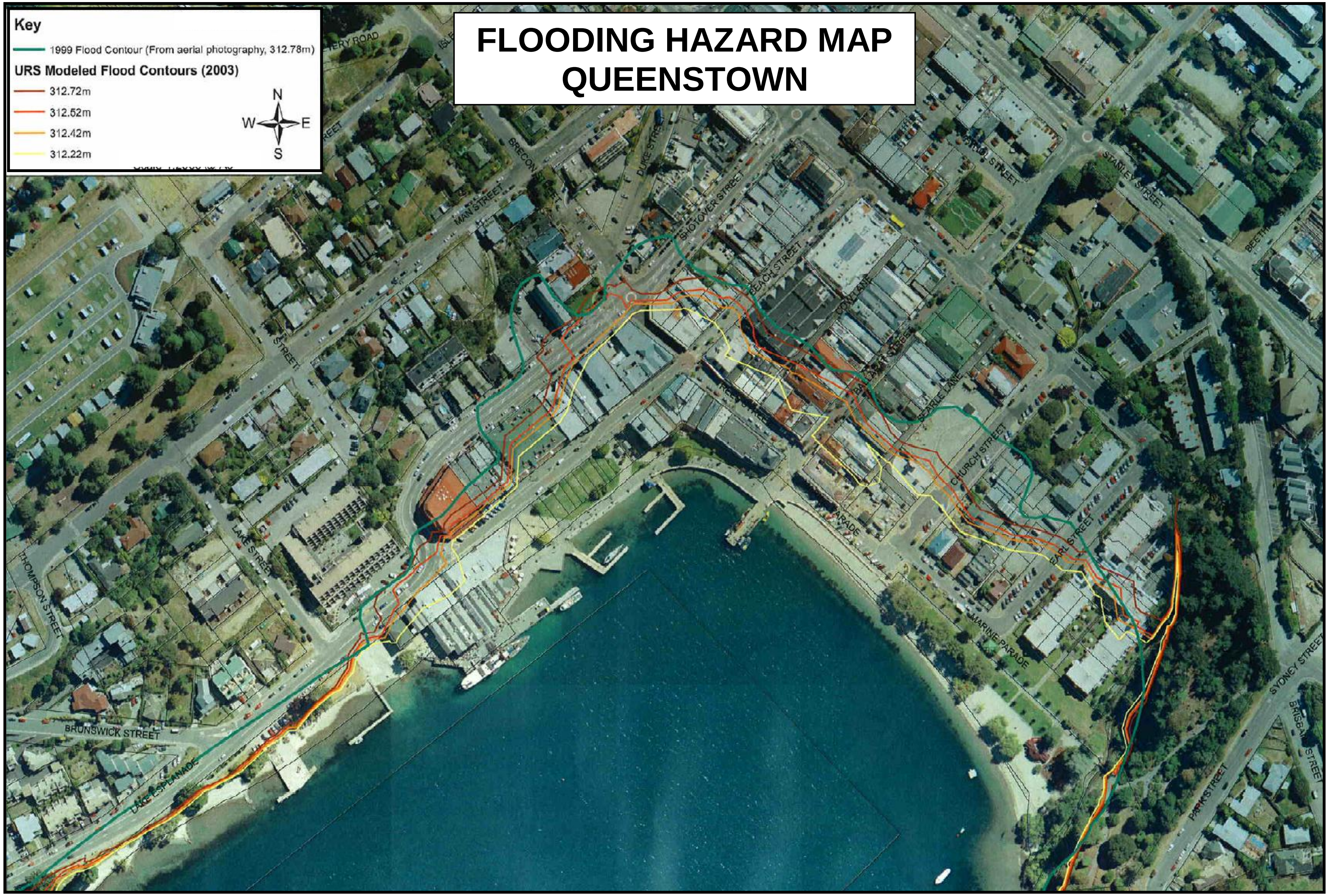
Disclaimer: Data for GIS maps are courtesy of the Queenstown Lakes District Council, GNS Science, Aurora Energy and Telecom NZ Ltd. Unfortunately permission was not given to reproduce the maps of the electricity network and telephone network and therefore these maps have been omitted from this thesis in accordance with copyright.

EARTHQUAKE HAZARD MAP
LOCATION OF FAULTS




EARTHQUAKE HAZARD MAP
AREAS SUSCEPTIBLE TO LIQUIFACTION
WANAKA
QUEENSTOWN
N
0 5 10 20 30 40
Kilometers


AREAS SUSCEPTIBLE
TO MASS MOVEMENT
KAWARAU GORGE
QUEENSTOWN
N
0 5 10 20 30 40
Kilometers


FLOODING HAZARD MAP
QUEENSTOWN
Key
1999 Flood Contour (From aerial photography, 312.78m)
URS Modeled Flood Contours (2003)
312.72m
312.52m
312.42m
312.22m
N
E
S
W
BRUNSWICK STREET
LAKE ESPLANADE
MARINE PARADE
CHURCH STREET
SYDNEY STREET
PARK STREET
THOMPSON STREET
STANLEY STREET
SHOTOVER STREET
BEACH STREET
EARL STREET
MAN STREET

FLOODING HAZARD MAP
WANAKA


FLOODING HAZARD MAP
GLENORCHY
Key
URS Modeled Flood Contours (2003)
312.72m
312.52m
312.42m
312.22m
N
W
E
S


Key
URS Modeled Flood Contours (2003)
312.72m
312.52m
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312.22m
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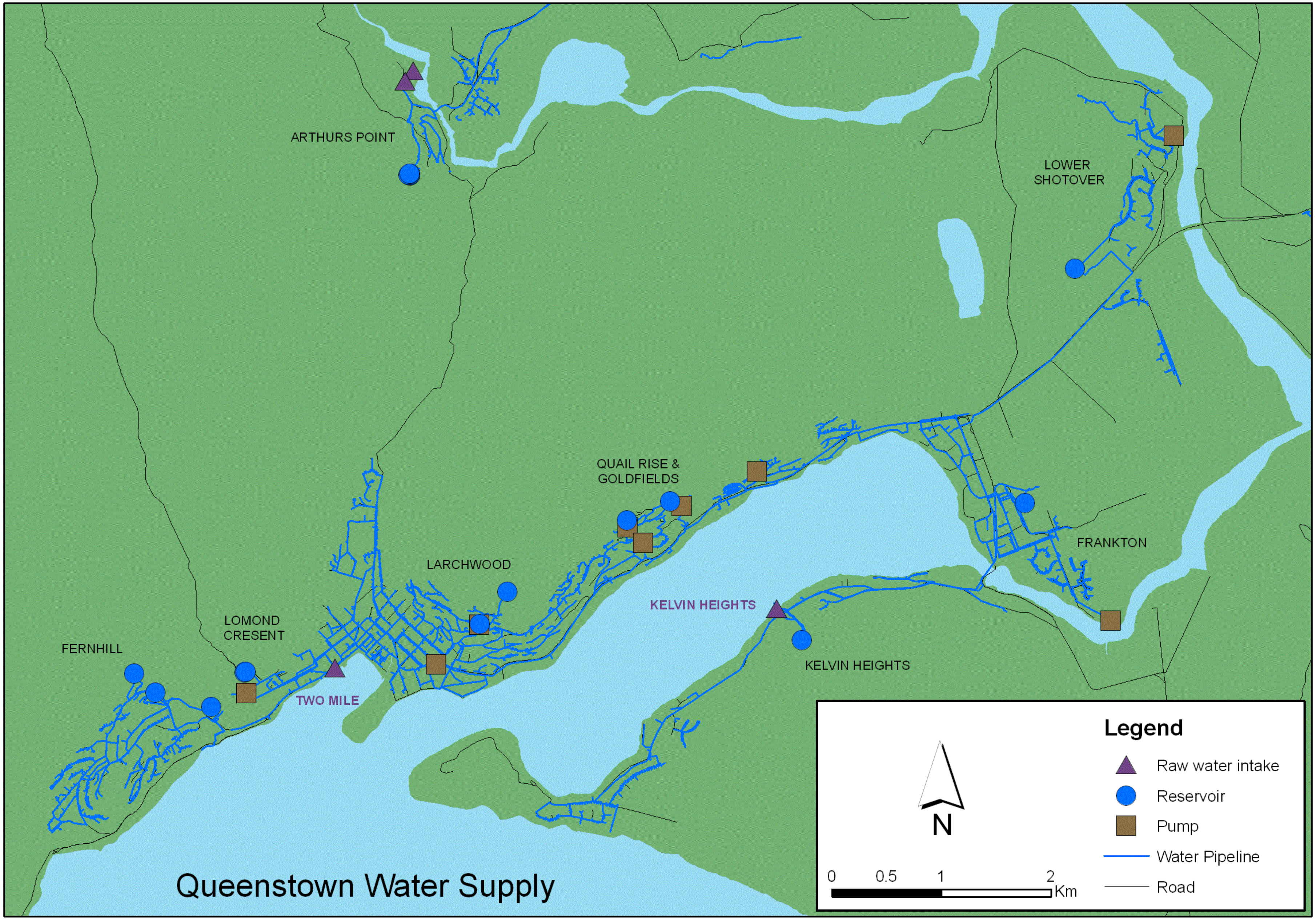
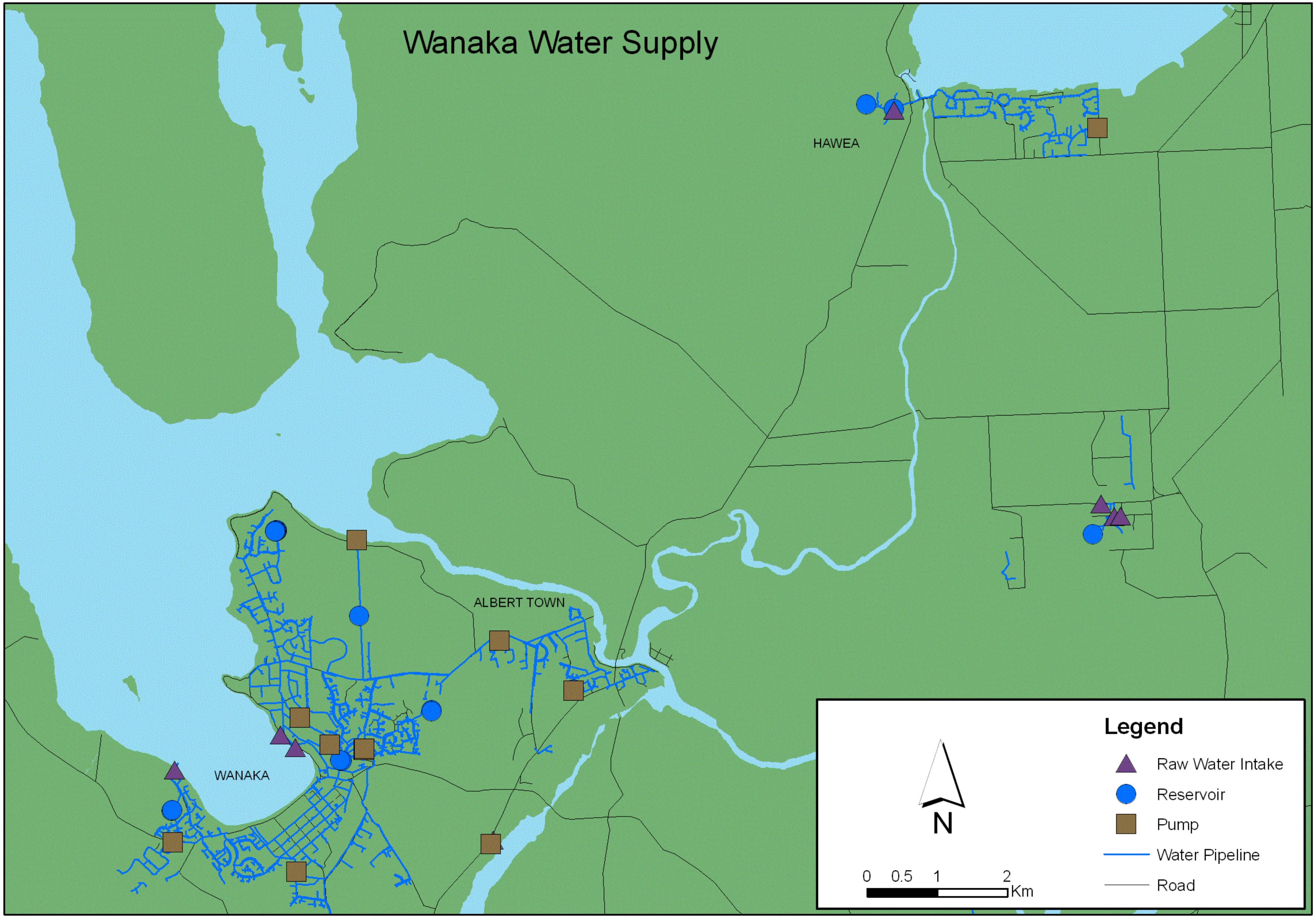
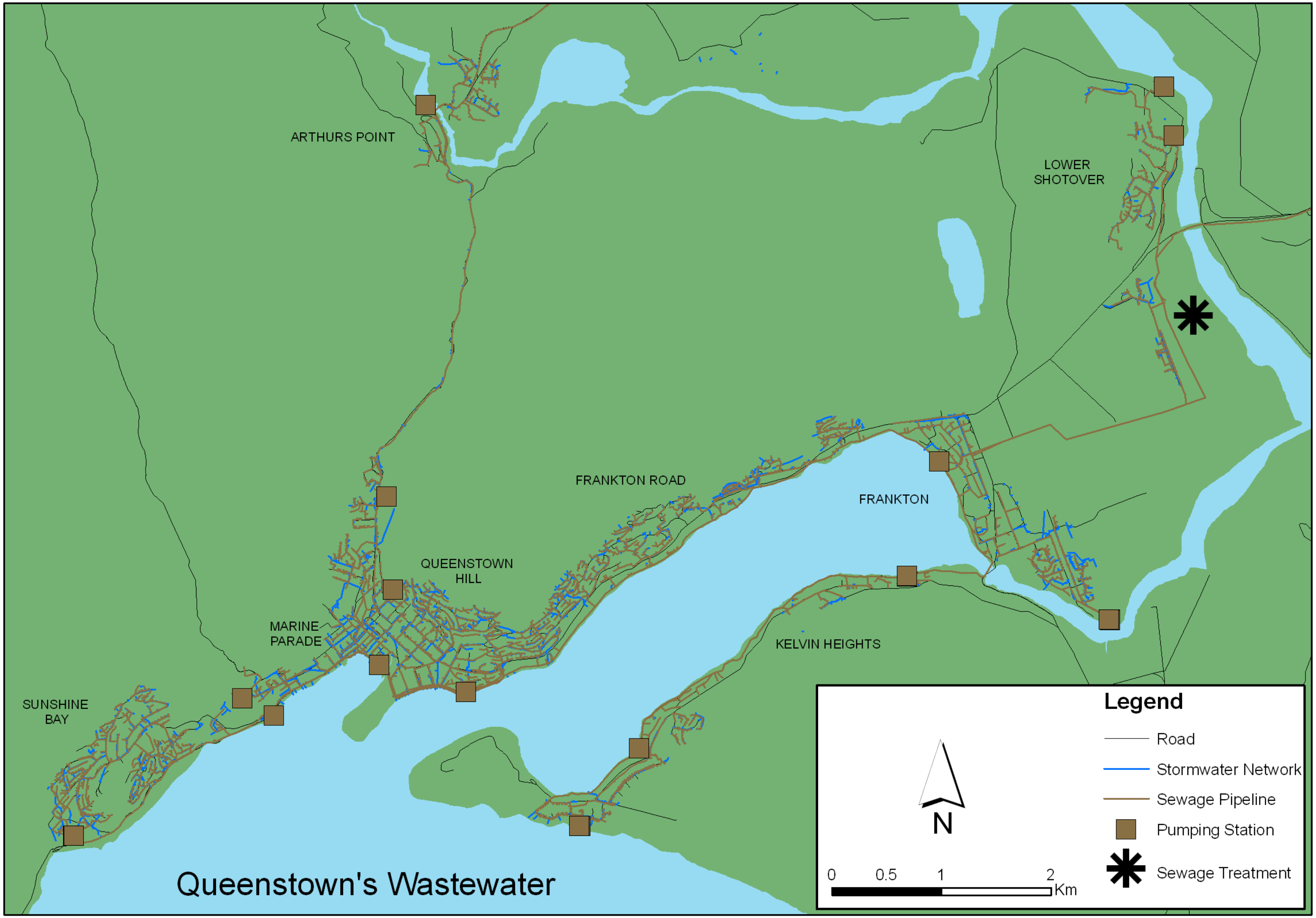
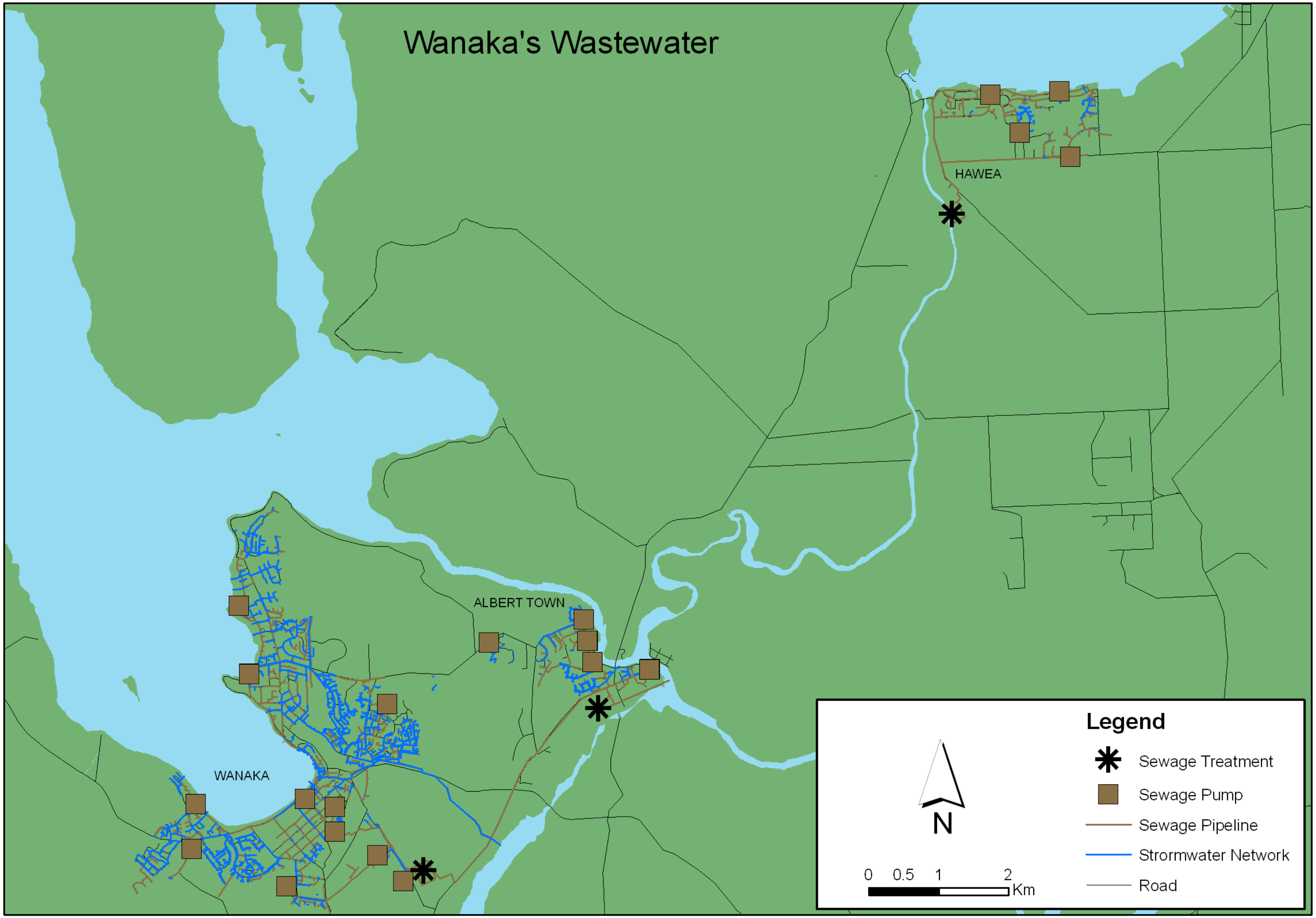
FLOODING HAZARD MAP
KINGSTON


ARTHURS POINT
LOWER SHOTOVER
QUAIL RISE & GOLDFIELDS
LARCHWOOD
FRANKTON
KELVIN HEIGHTS
KELVIN HEIGHTS
LOMOND CRESENT
FERNHILL
TWO MILE
Legend
Raw water intake
Reservoir
Pump
Water Pipeline
Road
N
0 0.5 1 2 Km
Queenstown Water Supply


Wanaka Water Supply
HAWEA
ALBERT TOWN
WANAKA
Legend
Raw Water Intake
Reservoir
Pump
Water Pipeline
Road
N
0 0.5 1 2
Km



ARTHURS POINT
LOWER SHOTOVER
FRANKTON ROAD
FRANKTON
QUEENSTOWN HILL
MARINE PARADE
KELVIN HEIGHTS
SUNSHINE BAY
Queenstown's Wastewater
Legend
Road
Stormwater Network
Sewage Pipeline
Pumping Station
Sewage Treatment
N
0
0.5
1
2
Km


Wanaka's Wastewater
HAWEA
ALBERT TOWN
WANAKA
Legend
Sewage Treatment
Sewage Pump
Sewage Pipeline
Stromwater Network
Road
N
0 0.5 1 2
Km

APPENDIX A: HAZARDS

EARTHQUAKES

In the 20th Century, more than 1.3 million people died in earthquakes around the world (CRED, 2007). New Zealand, which records more than 14,000 earthquakes a year, has more than 150 active faults that repeatedly rupture causing earthquakes. Fortunately only 200 of these earthquakes are large enough to be felt, however, the Queenstown Lakes District, due to its proximity to the Alpine Fault, and many other active faults in the Central Otago and Fiordland region is at serious threat from a major earthquake event (GNS, 2007).

The word earthquake is effectively a self-defining term – the earth quakes. An earthquake is a sudden shaking within the earth's crust caused by the release of accumulated strain. Earthquakes may be created by volcanic activity, meteorite impacts, undersea landslides, explosions of nuclear bombs, and more; but most commonly they are caused by sudden earth movements along faults.

Until fairly recently the Queenstown Lakes District was thought to be relatively free from seismic activity when compared with the rest of the country, and indeed records show very few earthquakes having been felt in this area. However in the last hundred years, several active faults have been discovered in the area showing movement across late quaternary (geologically young) surfaces, meaning that although seismic activity has been quiet in the past. The occurrence of earthquakes in the future should be anticipated. (Turnbull, 2000). This has been affirmed in the last few years where a number of small earthquakes have shaken the district.

The effect of an earthquake on a community can range from being a minor disruption to a major catastrophe, however it is important to note that it is not actually earthquakes that kill. The natural killers are the landslides and tsunamis that may accompany earthquakes rather than the actual earthquake. Most deaths occur when buildings and other structures collapse from the shaking. As well as the damage caused from collapsed buildings, interrupted supplies of water, electricity and gas and broken sewage and communication systems, uncontrolled fires and blocked roads and bridges can tragically disrupt lives and communities.

PLATE TECTONICS

The theory of plate tectonics explains why New Zealand is so prone to major earthquake activity. The theory is based upon the fact that the outermost layer of the earth (called the lithosphere) is broken up into several large tectonic plates which are constantly moving with respect to one another. These tectonic plates move across the surface of the planet carrying continents and oceanic basins on a soft and mobile layer of molten rock that is driven by heat originating from deeper within the earth. As these giant slabs move across the surface of the planet, they continually bump and grind into each other, and this constant pushing and shoving causes stress to accumulate within the earth's crust. Once the stress gets too great it is usually released in the form of an earthquake.

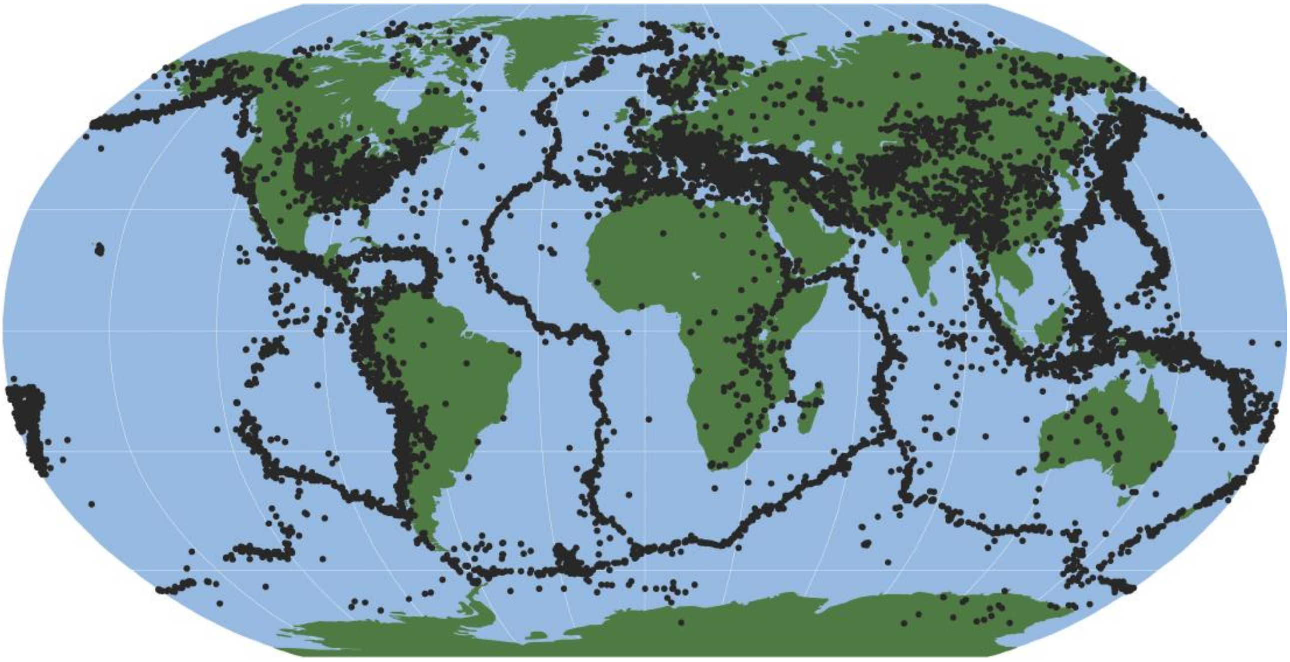


Figure 1: Plot of all the epicentres of earthquakes that occurred within the last century. These plots map out and define the edges of tectonic plates. The plate boundary of the Pacific and Australian plates runs directly through the middle of New Zealand.

New Zealand lies on the boundary of where two of these giant plates collide (figure 1). To the west stretches the Australian Plate, and to the east lies the largest and fastest moving plate of them all, the Pacific Plate (Aitken, 1996). This location astride two tectonic plates is the prime cause of tectonic stress in New Zealand and hence the reason for the large number of earthquakes the country experiences.

The specific mechanism controlling the plate motion underneath New Zealand is complex. The mechanism is complex because the Australian and Pacific plates are grinding together in three distinct ways: To the east of the North Island the Pacific plate is being forced under the Australian plate, under the South Island the two plates push past each other sideways and to the south of New Zealand the Australian plate is being forced under the Pacific plate (Cox, 1999). This complex situation makes New Zealand one of the most geologically active countries in the world, and one where the consequences of plate tectonics are highly influential and unavoidable. Most of the geographic features that characterise New Zealand are direct results of this setting.

SOURCES OF EARTHQUAKES

As these tectonic plates collide, stresses not only build up between the tectonic plates but they also build up in the over-lying crustal rocks, causing them to fracture, forming faults. A fault is a crack in the earth along which the rock on each of its two sides moves past each other. Once a fracture has occurred this fault becomes a zone of weakness and thus prone to further movement in the future. The purpose of a fault is to take some of the strain away from stress created at the subduction zone.

There are more than 150 active faults that are helping to relieve the accumulated strain that develops at the boundary between the Australian and Pacific plates (Aitken, 1999). An earthquake can be generated along any one of these faults, some of them being up to hundreds of kilometres in length and tens of kilometres in depth. The accumulated stress along these faults can either be relieved through frequent movement of the fault that is so small that it may not even be felt or alternatively the stress may build up over hundreds of years until one day the stress gets too great and when it can be contained no longer, until it is violently dissipated as a devastating earthquake.

The release of stress along one fault can increase the stress along neighbouring faults, raising the likelihood that they too will rupture in the future. Sometimes this in fact happens in a matter of seconds. Faults can behave in a number of ways (figure 2). Movement along a fault can be in any direction, and in fact, a combination of both vertical and horizontal movement occurs in most earthquakes. Faults are however, categorised into three groups:

1. A fault where the main sense of movement (or slip) on the fault plane is vertical is known as a dip-slip fault.
2. Where the main sense of slip is horizontal the fault is known as a transform (or strike-slip) fault.
3. Oblique-slip faults have significant components of both strike and dip-slip.

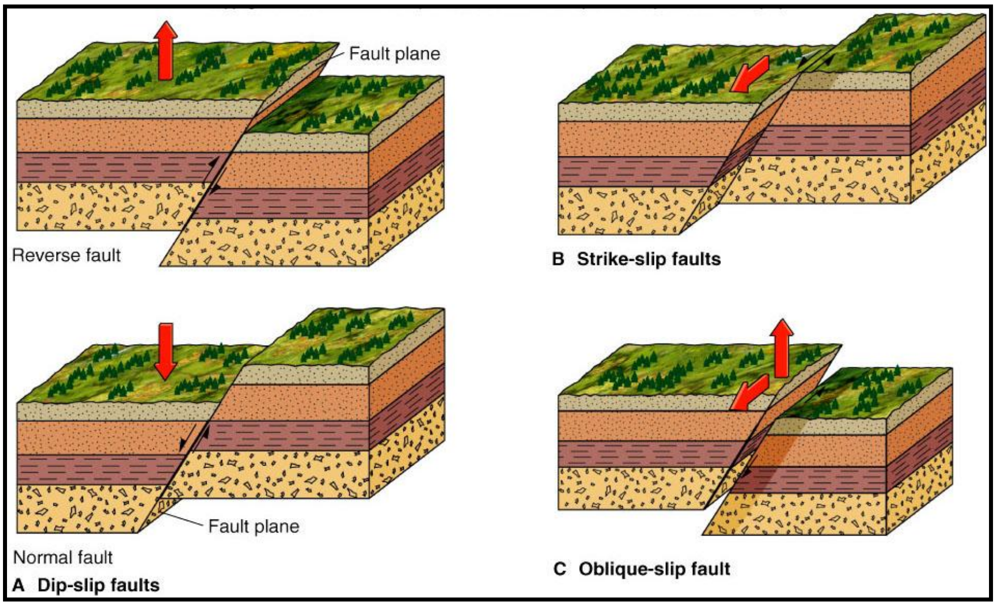


Figure 2: Diagram illustrating the types of faults

Each time an earthquake is generated by movement along a fracture or fault in the earth, it can leave behind a trace of its occurrence, like a scar from an injury to the body. Layers in the rocks have been displaced and offset by movements along the fractures: the amount of movement depends on the energy of the earthquake. Little earthquakes leave only little scars, but big earthquakes can leave large almost permanent scars. Over millions of years, the New Zealand landmass has continually been subjected to stresses and strains that have caused the earth to bend and crack. After hundreds of thousands or millions of years of movement, increasingly large vertical and horizontal separations of the land, have occurred (figure 3).

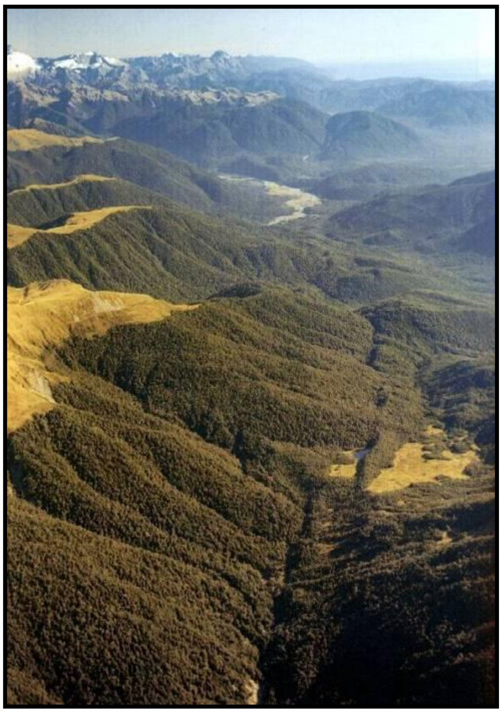


Figure 3: Looking south along the Alpine Fault, New Zealand's onshore plate boundary. Milford Sound is in the far distance (Source: Hicks et. al., 1998)

EARTHQUAKE MANAGEMENT

Earthquakes occur with little or no warning. Hazard and disaster management for earthquakes therefore relies on risk reduction and planning for response and recovery after the event. Although earthquakes are generally unpredictable the damaged caused by earthquakes is not and in most cases can be preventable. Ground-shaking during an earthquake is inevitable and can be regionally extensive, however buildings and other structures can be sited and constructed in ways that reduce the likelihood of damage and injury.

LAND-USE PLANNING

While widespread ground shaking is inevitable, some earthquake hazards can be avoided. Fault rupture occurs when the ground actually breaks apart along fault lines which have usually moved in the past. Therefore it is prudent to avoid situating structures or services across active faults and particularly traces such as those defined in the Cardrona Valley (refer to map two). Areas that may be susceptible to liquefaction can often be identified by their geology (refer to map three). Thus important facilities can be sited away from these areas, or the soil can be treated by compaction or other engineering techniques to reduce the risk.

BUILDING DESIGN AND CONSTRUCTION

Building collapses account for the majority of earthquake deaths worldwide. New Zealand however is a world leader in earthquake engineering and has relatively high building standards. Most residential homes are one or two story houses with light timber cladding which perform much better than un-reinforced brick or stones. A significant number of buildings however are still vulnerable, especially in the Queenstown Lakes District as they were built before the modern building standards came into force in the 1960's. Many road bridges in the area were also constructed before the 1960's. Modern bridges have lead rubber bearings positioned throughout the structure to isolate it from its foundations and help absorb the earthquake energy.

RELATIONSHIP BETWEEN MODIFIED MERCALLI SCALE AND RICHTER SCALE

The Modified Mercalli and Richter scales are used to rate and compare the intensity of earthquakes. The Modified Mercalli scale is somewhat subjective, because the apparent intensity of an earthquake depends on how far away from its centre the observer is located. The Richter scale on the other hand measures the motion of the earth's surface directly above where the earthquake occurred. The rating scale is logarithmic; each increase of 1 on the scale represents a tenfold increase in the motion of the ground.

MODIFIED MERCALLI SCALE		RICHTER SCALE	
I	Felt by almost no one.	2.5	Generally not felt, but recorded on seismometers.
II	Felt by very few people.		
III	Tremor noticed by many, but they often do not realise it is an earthquake.	3.5	Felt by many people.
IV	Felt indoors by many. Feels like a truck has struck the building.		
V	Felt by nearly everyone, many people awakened. Swaying trees and poles may be observed.		
VI	Felt by all, many people run outdoors. Furniture moved, slight damage occurs.	4.5	Some local damage may occur.
VII	Everyone runs outdoors. Poorly built structures considerably damaged, slight damage elsewhere.		
VIII	Specially designed structures damaged slightly, others collapse.	6.0	A destructive earthquake
IX	All buildings considerably damaged, many shift off foundations. Noticeable cracks in the ground		
X	Many structures destroyed. Ground is badly cracked.	7.0	A major earthquake
XI	Almost all structures fail. Very wide cracks in ground.	8.0 and up	Catastrophic earthquake
XII	Total destruction. Waves seen on ground surface, objects are tumbled and tossed		

MASS MOVEMENTS

Mass movement is the down slope movement of earth surface materials, snow or ice under the influence of gravity. This natural process is of fundamental importance in shaping the surface of the earth that we see around us. Some mass movement such as soil creep or glacial movement are too slow to be observable without precise instruments and although it presents a risk to some communities it can generally be efficiently managed to the point that it doesn't pose a serious danger to people or infrastructure. Other movements however may occur at faster speeds creating a serious and generally unavoidable threat. These types of mass movements occur at very high speeds; landslides and rockfalls are two examples of rapid earth movements. These movements can have disastrous consequences, both immediate and delayed (e.g. resulting from the formation of landslide dams)

New Zealand is far more vulnerable to mass movements than a lot of other countries in the world because of it position between two tectonic plates. The process that is responsible for the frequent earthquakes that the country experiences is also responsible for the uplift that the land experiences. The land underneath the Queenstown Lakes District is being rapidly uplifted by these tectonic forces at a rate of approximately 10mm per year (Hicks et. al., 1998). Opposing this upward growth are the relentless forces of climate and gravity that is responsible for much of the erosion that occurs within the district. Landslides or mass movements are one of the processes of erosion.

Mass movements can vary in size from a single boulder, that only cause minor disturbances, to movements that involve huge volumes of material that can cover many kilometres causing extensive damage to anything in its path. Mass movements generally occur naturally after rain, floods, earthquakes or even vibrations from thunder. They can be caused or made worse by human activity such as vegetation removal; creating unsupported slopes such as roadside cuttings; other excavation; or, increased soil moisture (from leaking water pipes etc). Downslope movement can cause enormous damage to infrastructure and properties and generally occur with little or no warning. Roads, homes, bridges, dams, airports and recreational areas can be destroyed, and at times cause injury and loss of life. Utilities such as pipelines, electrical wires, and communication towers can be damaged. No building regardless of its structural configuration, can withstand the effects of downslope land movement.

The geology and climate within the Queenstown Lakes District presents one of the most destructive natural environments in the country. Many of the distinctive shapes that litter the landscape have been sculptured by movement of rock and soils under the influence of gravity. Because of this and the high development currently being undertaken in the region this makes the Queenstown Lakes District particularly vulnerable to mass movements.

SLOPE INSTABILITY

Fractured, folded and crushed by earth's forces, much of the rock in the district is moving upwards, at a rate of about a centremetre a year, carrying the landscape higher and higher. Opposing this upward growth are two equally relentless forces trying to level the land; climate and gravity (Hicks et. al., 1998). The climate causes rain and snow which subsequently develops into rivers, streams and glaciers that gnaw at the land, carrying rocks to the sea. These natural processes continue to carve out valleys, growing ever deeper as time passes on, but there is a limit on how high and how steep valley walls can become. The natural slope of a valley's wall depends on the strength of the rocks that they are made out of. Eventually the force of gravity that is pulling the slope downward will exceed the strength of the rocks that is holding the slope together and land movement will eventuate.

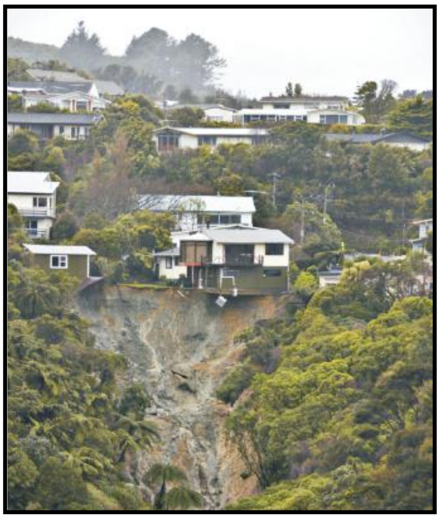


Figure 4: Landslide example in Wellington, 2006 (Source: Saunders et. al., 2007)

There are some inherent conditions that can make a slope more susceptible to failure, including the steepness of the slope, the nature of the underlying geology, the groundwater conditions and the level of human interference. These predisposing factors can exist for hundreds of thousands of years without any failures occurring. However each factor makes the slope more unstable and more vulnerable to failure.

CLIMATE

Mass movements in the Queenstown Lakes District are probably a natural consequence of glaciation, whereby glacial erosion of the basin floors and margins has tended to over-steepen the valley walls promoting instability. Frost/permafrost activity may contribute to the opening and loosening of fractures within the rock. In addition, slopes adjacent to glaciers may have been supported by the mass of ice, and the loss of support due to glacial retreat may have been a factor to the instability of slopes throughout the region.

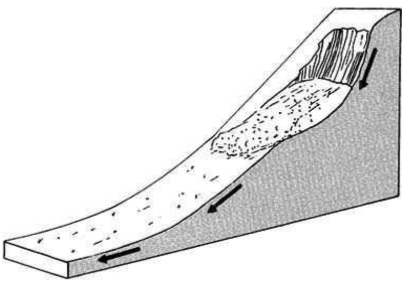


Figure 5: Diagram illustrating the relationship between landslides and slope steepness.

SLOPE STEEPNESS

The influence of slope steepness on movement occurrence is the easiest factor to understand. Simply, the steeper the slope, the larger the force and the faster the material will move downslope. This however does not mean the movements won't occur off gentle slopes. It just means that it is more likely. Few mass movements have ever occurred on slopes less than 15 degrees (figure 5).

GEOLOGY

The Otago schist that underlies much of the district has been fractured, folded and crushed so much by earth's forces that it has become extremely weak. Hence, these rocks are prone to instability and are the primary reason why mass movements in the district are so widespread.

The direction in which the schist is foliated is an important factor in determining where a landslide may occur. For example, in the Queenstown Lakes District the dip of foliation is generally to the west, therefore mass movements are more prone to occur on the eastern sides of the valleys, particularly if they are trending, north-south, like the Shotover. The type of schist is also important, and the mica-rich schist with its fine laminations is a much weaker rock than the quartz rich rock. This means that it is more prone to instability and breaks readily.

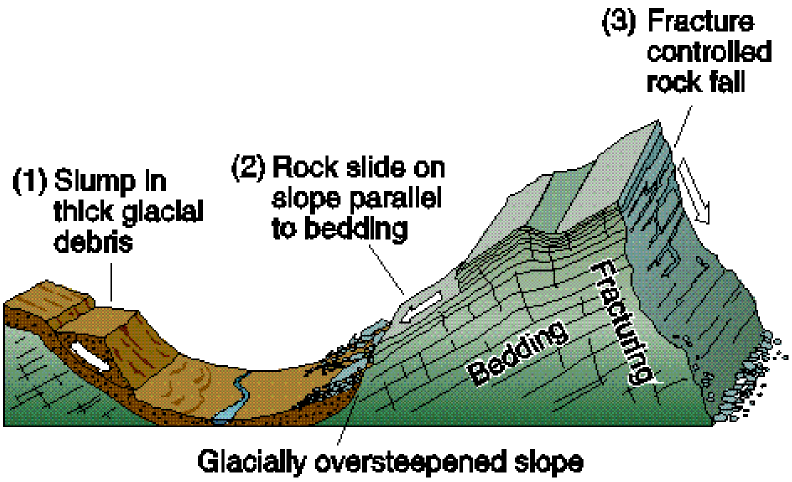


Figure 6: Diagram illustrating some of the causes and factors that dictate the nature of a landslide in particular the effect of geology.

Although mass movements are extensively developed on schist slopes within the district, there are a few locations where they have also developed on other slopes like those that comprise of glacial deposits. The principle factors influencing location, depth and nature of landslides are likely to be the nature, orientation and spacing of weaknesses (foliation, joints and faults) within the schist rock and the depth and the extent at which the schist is weathered (figure 6).

GROUNDWATER

Mass movements occur when the strength of the rock is less than the downwards pull of gravitation acting on it. The balance of these forces on a stable slope can be shifted either by increasing the weight of the materials or by decreasing its resistance to sliding. The influence of water on a slope can cause an imbalance of forces acting on the slope as water can increase the weight of the slope due to the over-saturation of the soils; water also decreases the frictional resistance of the slope therefore making it prone to movements.

Mass movements often accompany flooding or heavy rainfalls; this is substantiated from past movements in the district. From mid-winter to early spring mass movements are more likely to occur because this is when the water content in the soils is at its highest. During drier conditions, damage is likely to be confined to shallow landslides and rockfalls from cliffs. Quick and efficient drainage from a slope may prevent the ground in becoming saturated and thus may prevent instability.

HUMAN INFLUENCES

The steepness of the slope is not only controlled by the tectonic uplift in the area but can be influenced by human activity. For example, the slope may have been steepened by the removal of material at its base or an addition of material at the top. This modification to the landscape can cause an imbalance of the forces acting on a slope and thus increasing the risk of a mass movement.

- ***Removal of Vegetation***

  Vegetation contributes to both stability and instability. On jointed rock, shrubs and trees can promote instability, as the roots can open joints in the rock allowing the ingress of water, and may even prise blocks off slopes. On slopes with adequate soil cover, shrubs and trees are usually advantageous, as they add root strength, reduce concentrated overland water flow, and can alter the rate of water infiltration into the ground. Evapo-transpiration can also remove water from the soil. However, trees become a liability when they get very large – their weight and the action of wind can contribute to slope instability (Taylor et al, 1977). The removal of vegetation (often the first step in land development) can reduce the stability of sloping ground. Land originally stable under heavy bush cover commonly goes through a phase of slope failure when that cover is removed.

- ***Slope Modification***

  Modifications to slopes by development activities are a common cause and sometimes a trigger, of mass movements. In most cases, there is a time lag (sometimes several years) between the time that the slope has been modified to when a slope failure occurs (generally it requires another triggering event). Adding material to the top of the slope and/or removing material from the base of the slope will reduce the stability of the slope and hence the likelihood of slope failure. It has been widely recognised that this “cut and fill” type modification can have a profound effect on the stability of the slope. Examples of this type of slope modification occur when providing access ways for roads or other transportation networks which run across the sides of slopes (figure 7).

Figure 7: Development of the highway at the base of this slope in the Clutha valley has caused over-steepening of the hill side. Landscaping measures have been used to try and mitigate this hazard.

The excavation of materials at the base of a slope (especially if the slope has been active in the past) is the common cause of land instability in New Zealand. Although past land movements have displaced material into a more stable position, old landslide deposits are often weak and unsatisfactory to build upon. This is because its “softness” can lead to local ground settlement and recurring localised slumping for a very long time after the movement has ceased (Taylor et al, 1977) While this is not always the case, it still must be realised that this is a probable factor of landslide reoccurrence especially since many developments in the Queenstown Lakes District are being undertaken on ancient landslide deposits. For example: Queenstown Hill.

- ***Services***

  Services such as the local water supply reticulation system or wastewater network have the potential to rupture (especially if they cross area with evidence of past movement or fault lines) causing large amounts of water to infiltrate into the ground increasing the instability of the slope (figure 8). This is a secondary earthquake hazard that should be considered.

Figure 8: Abbotsford Landslide was first discovered when cracks in the ground were noticed by residents. A decade later engineers noticed that ground movement had caused water pipes to rupture. Two months later the slope catastrophically failed. (Source: Encyclopedia of New Zealand)

TRIGGERS OF MASS MOVEMENT

Mass movements can have several causes but generally have only one trigger. The most common trigger is prolonged or intense rainfall that over-saturates the rock and soil which causes an increase of weight and decrease of frictional resistance. Gravity then takes over and forces the land downwards. Large earthquakes are also capable of triggering land movements due to the intense shaking that results. Other triggers may include slope modification and erosion that results in the undercutting of slopes by rivers.

PAST MOVEMENTS

Interpreting the likelihood of future mass movement occurrences requires an understanding of the conditions and processes controlling past movements in the area. This can be achieved by examining the landscape and mapping past and potential movement areas. Past land movements may be identified by the presence of disrupted materials, but in many cases, their identification is principally based on certain geomorphic characteristics including stepped rippled or hummocky topography (for example the slopes of Coronet Peak), the presence of escarpments where the rocks have slid from and back-tilted benches. Recent active slides may still have bare patches on the slide itself where vegetation is yet to establish itself. General observations of exposed landslide materials indicate that landslide deposits range in composition from large transported blocks of schist to highly disrupted chaotic debris. There is little information on depths of landslide movement, but depths are likely to vary from a few meters for shallow landslides, to many tens of meters for deeper seated landslides.

Figure 9: Rockfall in the Kawarau Gorge blocking access for up to 3 days (Turnbull, 2000)

In the Queenstown Lakes District mass movements are a common occurrence especially within the Kawarau gorge where numerous rockfalls have created a travel hazard to motorists who drive through the region (figure 9). These rockfalls can cause major disruption to the transportation network throughout the district. This has major implications during an emergency such as a major earthquakes. Many of the active slopes in the district appear to be either dormant or creeping slowly (moving less than about 10 centimetres per year). However, there are landslides which, judged by surface morphology, are probably moving faster. Examples of these can be seen at Arthur's Point and on the slopes of Ferry Hill and on Sugar Loaf Hill (Turnbull, 2000).

EFFECT OF MASS MOVEMENTS

The effect of mass movements can be immediate and can be directly associated with the movement of land; or may manifest themselves over a longer time period. Most mass movement events are associated with other simultaneously occurring hazards such as rainstorms (that can cause flooding) and earthquakes. The force of materials moving down a slope can devastate anything in its path (figure 10).

The extent of the damage depends on the magnitude of the movement, the depth of the rupture surface and the type of movement. However any infrastructure situated on a landslide can be expected to suffer comprehensive damage if not total destruction. Mass movements can develop into different flows for example a landslide if it reaches water may develop into a faster moving debris flow which is likely to increase the extent of the devastation.

The greatest economic costs results from the impact on the landslide on physical infrastructure such as buildings, loss of transport and communications systems. Other indirect impacts result from the event recovery such as land rehabilitation and restoration of services.

Figure 10: Example of Landslide effects, Abbotsford Dunedin (Saunders et. al.,2007)

Death and injury by land movement is obviously the most tragic effects of mass movements, but sometimes a mass movement can cause indirect personal effects resulting from the trauma of the economic, social and emotional impact. A sometimes neglected aspect of large scale disaster is the debilitating psychological effect experiences not only by those directly affected by the event but also by family members, neighbours and relief workers.

LANDSLIDE MANAGEMENT

The best form of landslide prevention is simply to avoid building in landslide prone areas. If this is not feasible, lives can be saved by official warnings to evacuate homes when the danger of landslides is imminent. Landslides are often the result of human activities such as excavations, the denudation of hillside vegetation and the alteration of the pattern of natural drainage systems.

However there are situations when it is unavoidable to avoid building in these hazardous areas. Properly engineered construction can slow, deflect or trap moving debris flows. The key here is proper groundwater drainage and the diversion of surface water away from gully areas, which tend to focus downslope drainage. For this purpose rock fall chutes and debris run-out areas can be constructed in some areas. Mechanical stabilization of hillsides to prevent landslides is also possible. Revetments or barricades such as wickerwork fences and retaining walls of stone or concrete can be constructed to stabilize downslope movements. Anchors can be inserted into firm bedrock to minimise damage from movements of more mobile overlying rock and soil material. Treatment of steep angled slopes with gunite (a mixture of cement, sand and water sprayed onto a mould) is helpful, particularly if it reinforced with wire mesh. There is no guarantee however the engineering measures will withstand the worst case landslides.

METEOROLOGICAL HAZARDS

Meteorological disasters are extreme weather events that can wreak havoc on communities by destroying property, leaving injury and even death in their wake. Meteorological events by their very nature affect the whole of the region simultaneously and will disrupt many lifelines, including main access roads, the rail link, the airport, electricity supplies and communication.

Meteorological disasters are among the most frequent hazard threatening the district. The meteorological hazards that particularly affect the Queenstown Lakes District include heavy rainfalls, strong winds, tropical cyclones and snowstorms. Most of the time weather seems to be subtle and follows periodic trends that cause no real risk to people and infrastructure. However occasionally extreme weather phenomena do arise and present a serious threat to lifelines.

UNDERSTANDING WEATHER

Weather is created when the surface of the earth is heated by the radiation from the sun; the heated surface of the earth then heats the air above it, the air expands and rises, lowering the air pressure. This lowering of air pressure causes a system of low pressure to develop. As the air in this low pressure system rises it is rapidly replaced by the surrounding high pressure air, this movement of air from high pressure to low pressure is called wind and it is the driving force that controls many of the weather processes that we experience.

Another element that contributes to the formation of meteorological processes is water. Known as the fuel that drives the weather, water is responsible for such weather phenomenon as clouds, rain and snow. On earth, water is unique as it has the ability to exist in three physical states at the same time; vapour, liquid and solid ice. This ability is the reason why the weather on our planet is so chaotic.

The weather in the Queenstown Lakes District is largely dependant on the topography. Topography is not only an important factor on modifying national weather systems that move across the entire country but can also dramatically affect the local climate. For example the main divide of the Southern Alps separates the West Coast; one of the wettest regions in the country from the central Otago region which is one of the driest. The Queenstown Lakes District sits right in the middle of these two regions and experiences a variety of meteorological phenomena.

WEATHER SYSTEMS

The weather in the Queenstown Lakes District is dominated by the travelling anticyclones and intervening troughs of low pressure, which migrate eastwards every six to seven days. In spring the anticyclones follow more northerly paths and in autumn and winter, anticyclones follow a more southerly path. However the centres of these anticyclones generally always track north of the district over the North Island (Brenstrum, 1998). Anticyclones are areas of descending air, and settled weather, with little or no rain, which may bring clear skies or low cloud and fog.

Between the anticyclones are troughs of low pressure. Within these troughs there are often cold fronts, orientated northwest to southeast. As the front approaches from the west, northwesterly winds become stronger and cloud increases, followed by a period of rain for several hours as the front passes over, and then a change to cold showery southwesterly winds.

TROPICAL CYCLONES

Tropical cyclones are very rare, but are a part of the climate (figure 47). They are deep depressions that form in the tropics, often as hurricanes. As they move south towards New Zealand they usually curve eastwards and lose intensity before reaching as far south as Queenstown. Nevertheless, because climate change is having such a drastic and unpredictable effect on the weather the occurrence of huge amounts of rainfall with very strong winds should not be discounted.

Major disruption to many lifelines can be expected from an intense sub-tropical cyclone. Severe flooding will affect main roads and railway lines in low-lying areas and near the coast. Storm water systems will be overwhelmed and many overflows and burst pipes could occur. Slips and debris flows will be widespread in hilly areas, which could further disrupt lifelines. Other lifelines likely to be affected are electricity power lines, some telephone lines, the airport and main roads. People’s ability to move around may also be affected.

FLOODING

Floods are among the most destructive forces of nature and are generally the result of a multitude of naturally occurring and human induced factors, but nevertheless can be defined as the accumulation of too much water, in too little time, in a specific area. Flood effects can be local, impacting a neighbourhood or community, or very large, affecting entire regions. Floods can occur with little or no warning and can occur on all time scales ranging from several seconds to several hours.

Although floods are the most frequent and costly natural disaster in New Zealand (Hicks et. al., 1998), the danger that they present is often underestimated. The Queenstown Lakes District is no exception. Prided on a setting beside tranquil lakes and gentle meandering streams people are often oblivious to the fact that without warning these streams can become raging destructive torrents that fill the glacial lakes to the point that they overflow.

Figure 11: Lake Wanaka in Flood, November 1999 (Source: ORC, 2007)

Floods have always been an integral part of the natural environment in the Queenstown Lakes District. Unfortunately when people first settled in the district there was limited knowledge of the landscape and climate and it was natural instinct to settle and farm alongside rivers and lakes to take advantage of the fertile soils, freshwater and the transport links that these waterways provided. Consequently, the potential flood hazard wasn't recognised and the proceeding waterfront developments have created a significant hazard to people and property.

Since early European settlement in the 1850s significant floods in the Queenstown Lakes District have occurred on five separate occasions; 1878, 1924, 1994, 1995 and most recently and dramatically in 1999 (figure 11) when severe flooding in the district caused extensive damage especially in the communities of Queenstown, Wanaka, Glenorchy, and Kingston (Otago Regional Council, 2006). Despite the many devastating floods which have occurred following initial settlement in the district, development of the high value lake front is continuing and consequently is increasing the risk of flooding exponentially.

WEATHER AND FLOODING

Weather is undoubtedly the primary cause of flooding in the Queenstown Lakes District, and because of New Zealand's position in the middle of the South Pacific between two active weather systems, flooding can occur at any time of the year and may even occur without warning. The risk of flooding in the district however is substantially greater during spring and summer when rainfall is at its highest and is compounded by added runoff from snowmelt.

Heavy rainfall in the Queenstown Lakes District is dominated by north-westerly fronts moving over the southern part of the South Island (figure 12). If one of these fronts was to stall and remain stationary over the district for several days or more, it would cause sustained heavy rainfall in the lake catchments, forcing the water levels in the glacial lakes to rise. Fortunately, a single front does not usually increase water levels in the lakes sufficiently enough to cause a flood; rather it is a succession of fronts occurring without sufficient time for the lakes to recede that cause the lake levels to substantially increase.

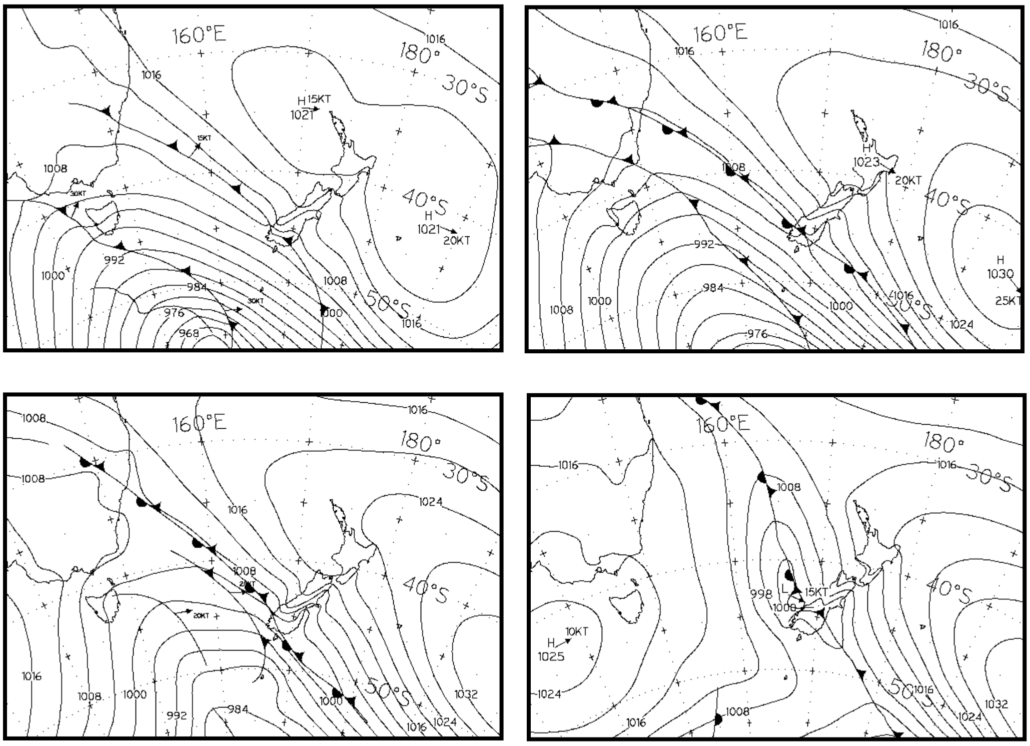


Figure 12: The maps show a slow moving north-westerly front moving over the southern part of the South Island from November 14th to November 17th, 1999. This storm resulted in severe flooding and disruption throughout Otago. (Source: NZ Met Service)

Due to the elevation of the Queenstown Lakes District during the winter months it is common for snow and ice to accumulate on the mountain tops. Over spring this snow and ice gradually melts away and flows into the alpine catchments. This excess water is generally the influential factor that forces the water levels to rise above the norm and into the streets of the lakeside communities. This is why most of the flooding in the district has occurred in the spring months from August to November and why the most likely time for the next flood to occur will be during this time.

In the Queenstown Lakes District, southerly winds commonly accompany high rainfall periods. If there is a strong wind during a flooding event the damage to structures in town can be exacerbated due to their exposure to wind-generated waves. Waves are generated in Lake Wakatipu due to its significant length and depth. Even within Queenstown Bay, the high lake levels during flooding events cause waves to break and run-up further inland, amongst the roads and building of the CBD, potentially causing damage over and above that arising from inundation due to high lake levels.

CLIMATE CHANGE

The effects of global warming further exacerbate the flooding hazard in the Queenstown Lakes District. Some climatologists believe that the effects of global warming will start to be felt within the next 100 years and that by the year 2100, average annual temperatures could be higher, by as much as three degrees Celsius; increasing the amount of rainfall by more than 14 percent, producing a 40 percent increase in river flows in winter and 13 percent loss in summer flows (NIWA, 2001).

Rainfall records for the Queenstown region indeed corroborate these theories by showing an increase of annual rainfall over time (figure 13). It also must be noted that in the second half of the 20th century annual rainfall totals are more extreme as opposed to the period from 1901 to 1950. Annual maximum levels for the glacial lakes also show an increasing trend with lake levels increasing approximately 0.4m in 75 years (ORC, 2007). This implies that the flooding hazard associated with the lake level is increasing, becoming worse and more frequent.

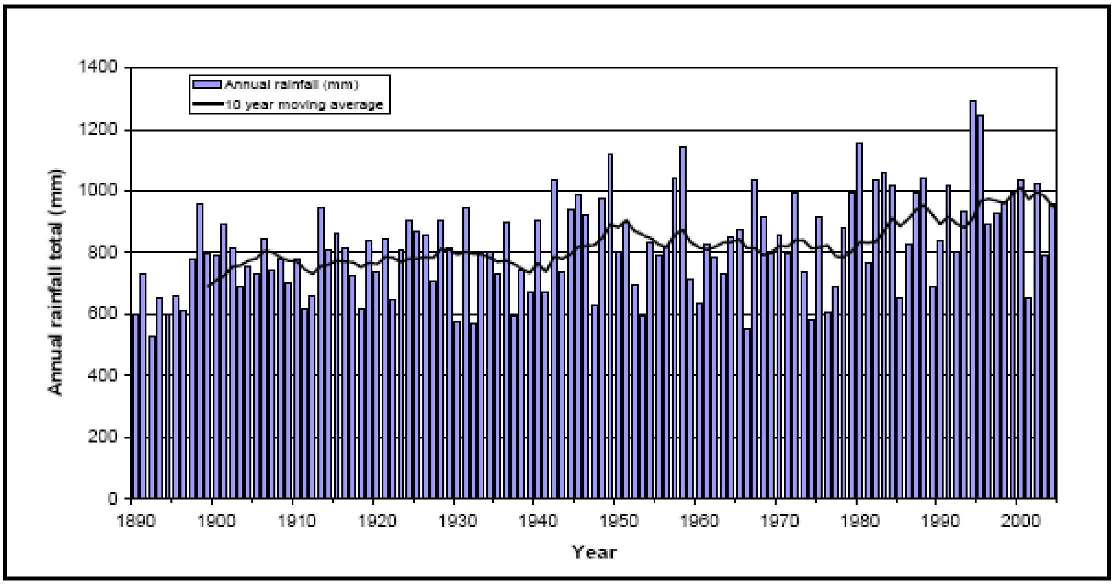


Figure 13: Queenstown annual rainfall totals 1890 – 2005 (Source: ORC, 2007)

FACTORS THAT CONTROL FLOODING

There are several other factors that control the extent of the flooding. Among these include rainfall intensity and duration, surface conditions and topography.

RAINFALL

The duration at which rain falls over the district is dependant on the speed at which the weather system moves across the country. Rainfall intensity is influenced by the topography of the surrounding mountain ranges. The angle at which the wind hits these ranges, along with the temperature and humidity of the air dictates the intensity and distribution of the rainfall over the district (De Lisle et. al., 1968). The extent of the flooding can be predicted simply by the amount of water the falls over the catchment (i.e. the more water that enters the system, the larger the extent of the flooding).

SURFACE CONDITIONS

Surface conditions also have a major influence on the extent of the flooding. For example areas that are highly vegetated soak in a lot more water than areas that are less vegetated. Human influences such as deforestation and urban development has exacerbated this situation as the increased runoff that occurs within these areas help determine the extent of the flooding.

Deforested areas increase runoff because with the absence of trees there is no longer anything to hold the soils to the forest floor. These soils together with the deep litter of fallen leaves that encourage infiltration, are soon washed away, creating rapid runoff and increased sediment loads. Loss of other vegetation such as grass can also have the same effect.

Urban areas also increase runoff because a higher percentage of the land is covered by impervious materials such as concrete, and tar seal. Buildings, roads and other paved areas are effectively waterproof and to remove the water from these surfaces channels and drains have been built that lead the storm water directly into the streams, rivers and lakes. There is no opportunity for the water to soak into the ground, leading to flooding downstream.

TOPOGRAPHY

Mountainous areas like the Queenstown Lakes District are more susceptible to flooding than areas with flat topography, as steep topography forces the water into the narrow valleys more rapidly producing discharges many times higher than the normal discharge of the river or stream. Other hydrological interventions such as land drainage systems also increase the extent of the flooding because the water is constricted to fixed channels such as culverts and storm drains thus increasing runoff.

FLOODING EFFECTS

Floods have an enormous impact on the environment and infrastructure of a community. Floods can destroy drainage systems, causing raw sewage to spill out into the streets creating a significant health hazard. Buildings and houses can be significantly damaged and even destroyed. This can lead to catastrophic effects on the environment, as many toxic materials such as paint, pesticide and gasoline can be released into the water contaminating rivers and lakes in the district. Floods can cause significant amounts of erosion particularly to river banks and shorelines, leading to further and more frequent flooding if not repaired. Landslides are also a hazard that can occur during flooding events. Although most of the effects that flooding creates are considered as negative, floods do make a slight positive impact on the environment. Floods spread sediment containing beneficial nutrients to topsoil that might never arrive there otherwise.

Figure 14: Looking down Rees Street November 1999 (Source: Otago Daily Times).

Major flooding events can cause millions of dollars in damage to homes and businesses. Indirect financial losses occur through loss of business whilst premises are being repaired, increased costs due to infrastructure disruption and in the longer-term when investment is discouraged by repeated floods. Major floods also result in considerable expense for Local and Territorial Authorities, the Environment Agency and Emergency Services - staff time, vehicle use, temporary community accommodation, and the cost of clean-up and repair of infrastructure. Flooding has major implications for the insurance industry.

Flooding can be dangerous. There is a risk of death and injury resulting from the flood itself, through to potential health impacts of contaminated water. Damaged houses can force people to be evicted from their homes as well as the distress caused by the loss of personal possessions and the time, effort and financial costs of organising the clean up and repair to property and the disruption of living in temporary accommodation. The experience of flooding can have a detrimental effect on health and wellbeing. Vulnerable people, such as the elderly are often the most severely affected and find it more difficult to recover from the emotional impact of the flood and the stress involved in restoring property. Communities are disrupted if people have to live in temporary accommodation in another area. An increased number of vacant homes whilst repairs are being carried may require extra policing as more patrolling is often needed due to the increased risk of crime.

FLOOD MANAGEMENT

Where and when rain falls cannot be controlled but what happens to the water once it reaches the ground can be influenced to reduce the flood hazard. Decreasing the rate of runoff into streams and containing the flood within the river channel are two measures that can be taken. However, these measures cannot eliminate flooding, and land will still occasionally be inundated. The consequences depend on how communities choose to use flood-prone land. Today, with structural protection works, monitoring and warning systems, floods claim few lives, but they still regularly cause millions of dollars worth of damage to structures, infrastructure, and agriculture. Reducing the flood risk in the Queenstown Lakes District involves managing the entire glacier lakes system from the high alpine catchments, the rivers and streams that flow through the region and the great lakes of Wakatipu, Wanaka and Hawea.

There are two common mitigation measures that are used to keep people and property away from flood prone areas. These include structural measures and non-structural measures. Structural measures traditionally have focused on building structures to keep water away from people such as using stop banks and flood protection walls. Caution must be taken when adopting this practice as if instigated without research; this option can have an adverse effect. A recent more popular approach to flood management involves non-structural measures such as land-use planning and adopting building standards to keep property above flood levels. Effective flood management generally requires a combination of both structural and non-structural mitigation options.

Figure 15: Sandbagging Wanaka Township November 1999 flood (Source: QLDC, 2006)

STRUCTURAL MEASURES

Flood protection structures such as stop banks, groynes, detention dams and flood gates all aim to modify river behaviour. The negative effect of structural measures such as stop banks often provides a false sense of security and people often develop behind them. Unfortunately the protection structure will eventually fail either due to poor construction or maintenance or through flood exceeding their design capacity and this can increase the risk to a community exponentially. Physical mitigation measures can also be costly to build and maintain.

Structural measures also include maintaining the capacity of river channels through realignment of river bed gravel extraction. It is important to note that a lot of structural flood control measures can have secondary effects on the environment. They can affect sediment transport and deposition and ecological habitats. Structural measures can be an important component of floodplain management but the costs and benefits must be appropriately managed across social, economic and environmental values.

Numerous theories on how to manage flooding in the Queenstown Lakes District have been proposed over the years. Many of these ideas have focused on controlling the lake levels through physical measures such as physical works in the Kawarau River. Unfortunately such reliance on physical works has been challenged by the complexity of the natural setting. For example, communities further downstream became more vulnerable to the flooding hazard, due to measures undertaken to benefit upstream residents. Thus authorities have conceded defeat and now acknowledge the fact that flooding is a natural consequence of living near the lakes and are focusing on reducing the impact and risk through proper management and non structural measures such as developing emergency response plans.

NON-STRUCTURAL MEASURES

The simplest way to reduce the risk of flooding is to not develop in flood prone areas. This is relatively easy to do in undeveloped sites where flood prone land can be used for parks, sports field or car parks rather than housing or infrastructure. However in existing flood prone communities discouraging further development is often difficult and generally involves complex political, social and economic issues. The key to avoid flood prone areas is to mark the areas at risk from inundation on a map, then to assign building restrictions to that zone. This concept is commonly known as land-use planning. Another form of non structural mitigation may involve planting of vegetation to stabilise land and to help absorb water in order to reduce the rate at which it enters the river system.

Figure 16: Moveable Shelving and Hard Flooring (Source: ORC, 2007)

FLOOD MONITORING AND FORECASTING

The earliest indications of potential flooding in the Queenstown Lakes District are the heavy rain warnings issued by the by the New Zealand Meteorological Service. The Met Service issues a Severe-weather warning when more than 50mm of rain is expected within the following 6 hours or when more than 100mm is expected within the following 24 hours (Met Service, 2007). Upon receipt of a Special Weather Warning, the Otago Regional Council then distributes it by fax to the Queenstown Lakes District Council and other Local Authorities, Civil Defence Groups, farmers with flood prone land, the Department of Conservation, ski fields and the media.

The NZ Met Service can also issue a ‘severe weather watch’ if there is a Preliminary indication that heavy rain may affect a certain area with in the next few days. Watches tend to be distributed only to local authorities, and the public is not notified unless there is very good reason to do so. Severe weather outlooks can be issued for severe weather which could occur 3 - 6 days ahead (Met Service, 2007).

The Otago Regional Council has the primary responsibility for flood forecasting and public warnings in the district. In order to efficiently undertake this responsibility the council has direct 24-hour access to the lead Met Service forecaster who issues heavy rain warnings and also maintains there own network of remote stations that monitor river flows and levels, lake levels and rainfall - fundamental to flood warning and forecasting.

Monitoring sites are operated by the Council, either independently, or in conjunction with the National Institute of Water and Atmosphere (NIWA), Trustpower, or Contact Energy. The method by which information from these stations is transmitted to the Council is either by satellite, cellphone or landline. The frequency at which these stations monitor and transmit rainfall and river levels can be manually set by the council depending on the nature of the situation, but generally they record the level of the water at 15 minute intervals.

In addition to the normal updates of information via the telemetry system, there is a separate alert system that automatically sends warning messages to the authorities. If river and lake levels reach a certain height or flow, and rainfall above a certain intensity an automatic alarm will be sent to the authorities. Warning times can be relatively short because many of the catchments are short and steep resulting in rapid runoff. The Otago Regional Council however tries to prevent this by monitoring the rate at which the water enters the system and installing multiple alarms at the same site that are triggered at different levels.

APPENDIX B: LIFELINES

ELECTRICITY

Electricity is naturally occurring and despite its great importance in our daily lives most of us rarely stop to think of what life would be like without electricity. Like air and water we tend to take electricity for granted. Everyday, we use electricity to light and heat up our homes, we use electricity to cook our food, power our computers, TV's, and other electronic devices. These are the most obvious uses of electricity but there is much more. Electricity is also essential for removing sewage, providing water into our homes, and is also important for telecommunication. Unfortunately electricity runs through just about every mechanical device that we use creating a large dependency. Without electricity, life can be very difficult for many people.

Very simply, electricity is the 'flow' of electrons. To generate a steady flow of electricity we need to make the electrons move, this can be done using magnets. If you move a magnet near an electrically conductive wire, the magnetic field will cause the electrons in the wire to move. In order to have a continuous supply of electricity these magnets must be kept constantly moving. This principle is used in power stations to generate electricity.

Electricity has radically transformed and expanded our energy use and to a large extent, electricity now defines the modern technological civilization. The modern day electricity supply to the Queenstown Lakes District can be divided into three main components before the power arrives at the consumer; generation, transmission and distribution (figure 1).

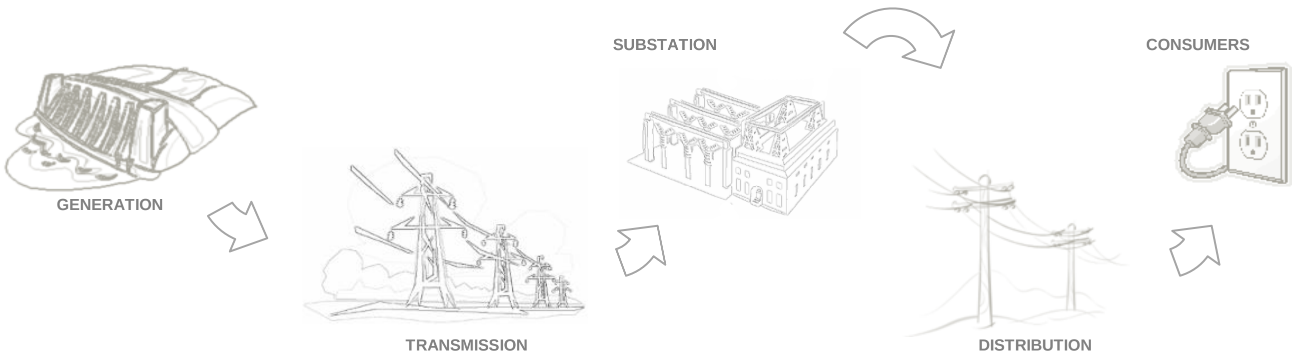


Figure 1: Electricity Network

ELECTRICITY GENERATION

Electricity generation is the first process in the delivery of electricity to consumers and involves converting some form of energy into electricity. In New Zealand most electricity is generated from hydro-electric power stations (of the approximately 60 power stations in New Zealand, 40 or them, are hydro-stations). The rest of New Zealand’s electricity is generated from such resources as wind, gas, coal or geothermal resources (Electricity commission, 2007).

In the Queenstown Lakes District there are two small hydro-electric power stations one at the outlet of Lake Hawea, the other in the Kawarau Gorge. These are respectively called the Lake Hawea and Roaring Meg power stations. These power stations do not directly supply the district with electricity. Once electricity is generated it is instantaneously supplied to the national grid for distribution throughout the country, no matter where the power station is located. Because electricity cannot be stored, the instantaneous generation must match the demand being taken from the system. If the demand is greater than the supply, the system frequency will fall and alternately if the generation is greater than the demand, the frequency will rise, thus causing system failures and blackouts.

Electricity is generated by electro-mechanical generators that convert mechanical energy into electrical energy. This process is based upon the principle that when a magnet is moved near a wire an electrical current will flow in the wire. At a typical generation station, electricity is generated using a turbine (figure 2). Driven by the force of water, wind or high pressure steam turbines rotate huge magnets that are located within a ring of copper coils. As these magnets rotate a current is induced within the coil of wire. This current is the electric power that is sent to the national power grid.

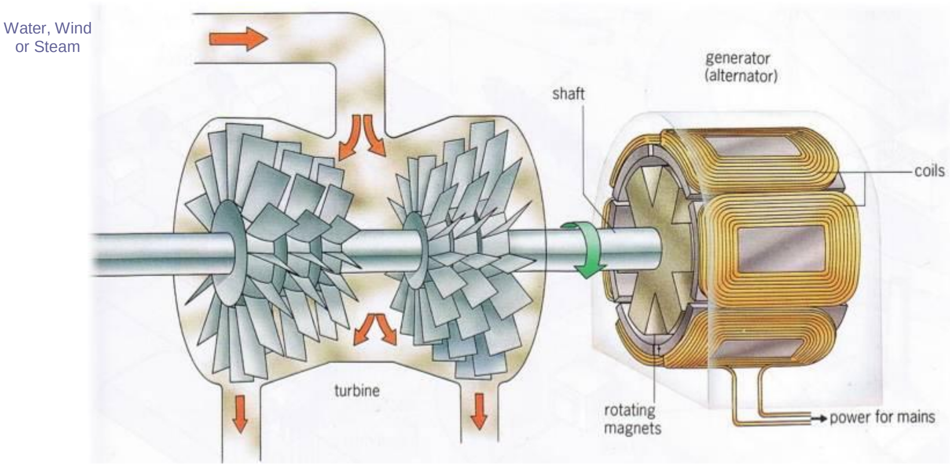


Figure 2: Diagram of an electro-magnetic generator used at a typical power station.

In a hydroelectric station, the turbines (that rotate the magnets) are turned by water falling through them; in geothermal, coal, and natural gas electro-stations they are turned by the steam produced when fuels are burnt to heat water; and wind turbines harness the force of the wind to turn the rotors. There is no one power station that supplies the Queenstown Lakes District. Once electricity is sent to the national grid it is then divided up and sent where it is needed. Therefore, if there is a failure within one power station, other stations can pick up the slack providing some redundancy to the system. However, if electricity generation can not meet the demand of the country then some areas may experience blackouts.

Outside every electric generation station there is a substation which uses a transformer to increase the voltage of the electricity before it is supplied to the national grid.

ELECTRICITY TRANSMISSION

Electricity moves at nearly the speed of light; that is almost 300,000 kilometres in just one second. To transport electricity from a power station to the Queenstown Lakes District, a transmission medium is required. The best medium to carry electricity is a conductive metal such as copper or aluminium. These metals are formed into wire which, carry the electricity throughout the country in a transmission network called the "national grid".

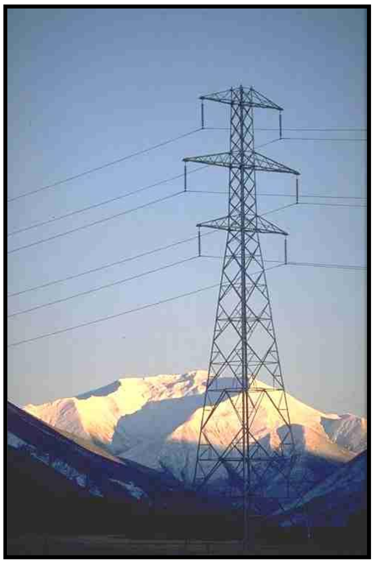


Figure 3: Transmission Lines

The national grid is unique as it is designed to move electricity at tremendous speeds over extraordinary distances (figure 3). In fact electricity is so fast that it generally arrives at the destination at almost the same moment as it is produced. Since there is no long term storage capacity for electricity it normally flows over all available paths to reach the customer and it cannot be easily directed in one particular way.

The national grid is the physical hub of the electricity network in New Zealand and is made up of over 12,000 km of transmission lines (Transpower, 2007). These lines transmit electricity at high voltages (up to 220,000 volts) from the power stations to a transformer substation located near a populated area (figure 4). Transformer substations reduce the electricity to lower voltages (110Kv and 33Kv) for distribution on local networks. Electricity is transmitted at higher voltages to reduce the amount of energy lost within the system.

There are two transformer substations that supply the Queenstown Lakes District with electricity, one in Frankton and one at Cromwell. Frankton substation primarily supplies Queenstown, Glenorchy, Arrowtown and surrounding areas with electricity, whereas the Cromwell substation supplies the entire district (including supply to the Frankton substation). The Cromwell substation is therefore considered to be more important than the substation at Frankton.

Figure 4: New Zealand’s National Grid (Source: Transpower NZ Ltd)

The Cromwell substation receives electricity from two 220kV transmission lines. One line comes from the south travelling up through the Clutha valley on the flanks of the Old Man Range via Clyde from Roxburgh. The second high voltage transmission line comes from the north travelling through the Lindis Valley from Twizel. Two high voltage transmission lines feeding into the same substation provides some redundancy to the system, whereby an outage on one line (depending on the day/time of year) may not affect the supply into the district. However, if there are failures across both lines then electricity supply may be lost for several weeks until the damaged components are fixed.

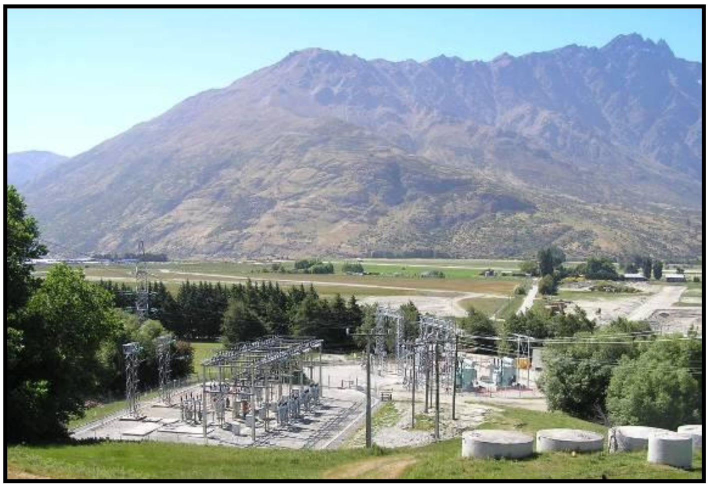


Figure 5: Frankton Substation

The Frankton substation (figure 5) is supplied with electricity from the national grid via Cromwell through a single 110kV transmission line. This line travels down through the steep and narrow Kawarau Gorge which is renowned for its rockfalls and landslides. As there is only one transmission line feeding into the Frankton substation, electricity supply along this route is considered more vulnerable.

The management of this electricity including how much is needed and where it must go is controlled at national co-ordination centres located in Hamilton and Wellington. These centres can run independently from one another if one becomes damaged.

ELECTRICTITY DISTRIBUTION

Electricity distribution networks in the Queenstown Lakes District carry electricity from the transformer substations at Frankton and Cromwell to industrial, commercial and domestic users. Electricity is supplied to the Queenstown area via three 33kV transmission lines from Frankton. Two of these lines are beside SH6A on Queenstown Hill and the third goes along the Shotover River through Arthurs Point. All three lines combine at the main area substation behind the Queenstown Primary School.

In Wanaka the power is supplied via two 66kV transmission lines from Cromwell. These lines run on either side of Lake Dunstan and join at Queensbury before going to the Wanaka substation along Ballantyne Road. From the substations 11kV feeder lines and cables send the electricity throughout the district to commercial, industrial and residential consumers. However, beforehand the electricity must pass through a series of transformers which transforms the voltage to 240V for the low voltage network.

Transformers transform voltages from high to low or the reverse. Electricity may flow through several transformers before it reaches the consumer. Substations generally contain one or more transformers and have switching, protection and control equipment. Circuit breakers and fuses are used to interrupt any short circuits or overload currents that may occur on the network. An important function performed by a substation is switching. Switching is the connecting and disconnecting of transmission lines or other components to and from the system while maintaining supply to an area. For example when adding or removing a transmission line or transformer the system must be kept running. Another component of a typical substation is a distribution bus that is used to spilt the electricity in multiple directions so that it may be distributed throughout the region.

Other communities within the district are generally supplied by 11kV feeder lines from the Queenstown and Wanaka substations apart from Kingston who is supplied with electricity from the south by The Power Company Ltd. Electricity from the Queenstown and Wanaka substations still needs to pass through another set of transformers to reduce the voltage before being distributed throughout the community. Within urban areas low voltage link boxes are placed within the roadway or footpath (figure 6). The low voltage link boxes contain electrical switch gear, allowing isolation of properties and sections from the low voltage network. Feeds are then taken from the low voltage link boxes to the individual consumers, with Delta ownership and responsibilities finishing at the junction box within the consumers building. Within a building, the power supply would be divided into several circuits, allowing isolation of that circuit.

Figure 6: Electricity distribution network: Queenstown substation behind the primary school (top left) and Wanaka substation on Ballentyne Road (bottom right). Electricity transformer located along a residential street (bottom left) and low voltage link box (black box) located outside a residential home (top right)

TELECOMMUNICATION

Telecommunication has developed into an essential part of a community's infrastructure with most people unable to live the way they do without their mobile phones and internet. During a major disaster, such as an earthquake, it is expected that telecommunication systems will be damaged for a number of days; usually due to the collapse of antennas, buildings and the loss of power. The use and function of communications infrastructure during and after a disaster is not only vital for survivors to establish contact with emergency services, but is also important for informative messages to be communicated to the public. Messages can be sent in a variety of ways by a wide range of devices. In the Queenstown Lakes District there are two types of networks that allow people to communicate with one another; the telephone network and the broadcast network.

TELEPHONE NETWORK

The telephone network (figure 7) uses both wires and wireless methods to deliver voice communications between people and data communications between computers. Wire based communication uses copper wires and fibre-optic cables to provide a link between telephones and exchanges. Wireless communications use technologies such as mobile telephones, pagers, satellites and microwave transmission.

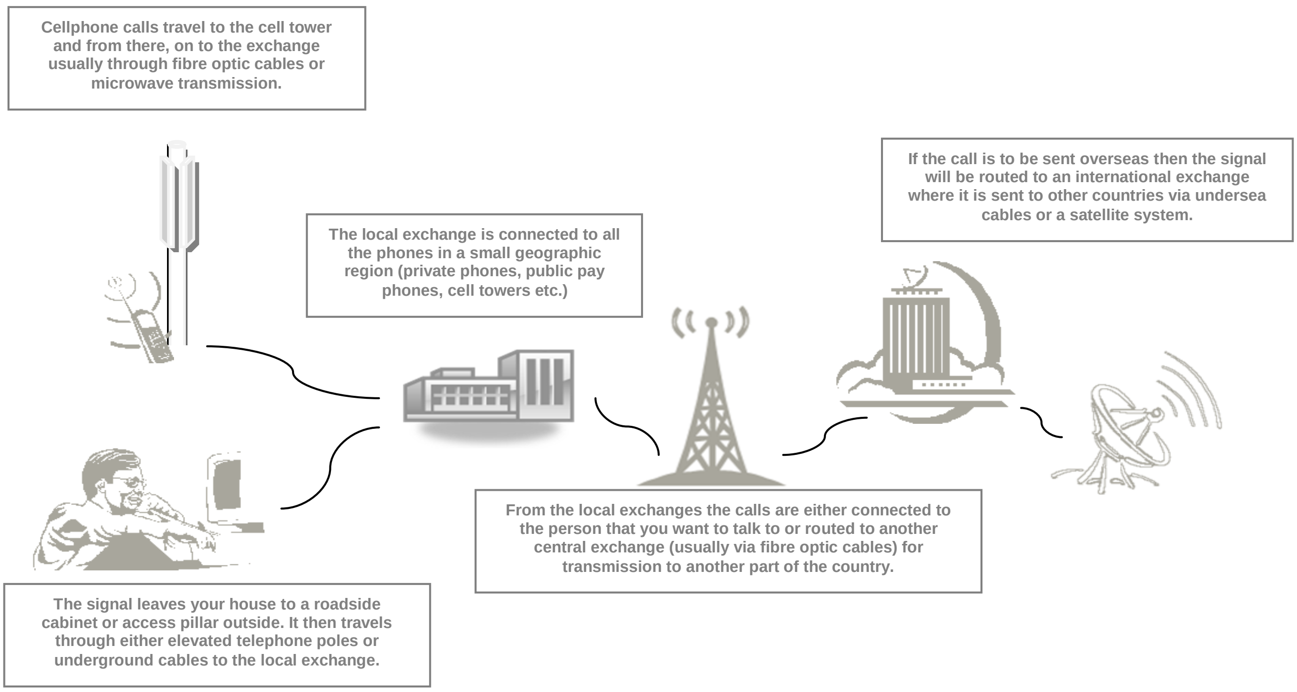


Figure 7: Systematic Diagram of the Telephone Network illustrating the process in which people communicate with one another across geographic distances.

Telecommunication supply to and from the Queenstown Lakes District is provided by a primary fibre optic line through the Kawarau Gorge from Cromwell and a digital microwave system. These fibre optic lines feed into both Queenstown and Wanaka central exchanges a digital microwave transmission system feeds into the Queenstown central exchanges to provide some redundancy to the fibre optic lines. At the present time there is also an additional line being installed from Queenstown to Invercargill that will loop the fibre optic line around the main population centres in the South Island. Once this has been commissioned it will provide partial redundancy to the system, by providing two routes into the Queenstown Lakes District. (i.e. if one section of the loop is severed, the information can be transmitted from the other direction)

From the central exchanges the supply is then distributed to roadside cabinets, access pillars and internal or external termination points by a copper cabling distribution system which acts as "feeder cables" between the components. Some high end users in the district use their own isolated fibre optic distribution system to transmit the supply from the exchange directly into their own premises. The supply then reaches the individual owned and maintained telephone systems and computer/data systems within their own premises.

The mobile telecommunications system uses primarily the same components as the land based telecommunications system however instead of a copper cabling system distributing the supply; cellular base stations (cell towers) and a repeater station located at Queenstown's central exchange receives cellular signals and transmits them back via wireless technology.

The telecommunication systems are constantly being upgraded to meet the increasing demands of telecoms users. This means that the size and number of some of the telecommunication components listed above are getting larger and closer together, particularly the roadside cabinets. Many of the above components require power, normally provided by mains electricity.

FIBRE OPTIC TRANSMISSION

Fibre-optic cables are used by Telecom to transmit telephone signals, internet connection and cable television signals, sometimes all on the same optical fibre. Fibre optic communication is a method of transmitting information from one place to another by sending light through long thin strands of very pure glass about the diameter of a human hair. They are arranged in bundles called optical cables (figure 8) and are able to transmit hundreds of thousands of telephone calls with absolute clarity.

Figure 8: Fibre Optic Cable displaying individual strands

Voice signals are turned into a selection of dots and dashes just like Morse Code and encoded by a computer down one of these glass fibre strands. These glass fibre strands take this computer signal and sends it from one part of the country to another. In New Zealand there is over 40,000 km of optical fibre in use and it is this super basic infrastructure within the country that allows us to bridge connections. New Zealand has multiple routes across the country, such that if there are problems of any sort such as an earthquake, that severs a connection, a computer will detect this problem and automatically reconnect telephone traffic over a different route.

Optical fibre transmission is often preferred over satellite transmission especially when calling internationally. This is because the distance to and from the satellite are so great that even when travelling at the speed of light it results in a quarter second delay and an annoying echo at the receiving end to the line. Optical fibre cables also provide many times the capacity of the satellite with absolute perfect clarity and no delay.

DIGITAL MICROWAVE TRANSMISSION

Digital microwave transmission is a technology for transmitting signals such as long distance telephone calls between two locations on a line of sight radio path (figure 9). In microwave transmission radio waves are transmitted between the two locations with directional antennas forming a fixed radio connection between the two points. The existence of this digital microwave system provides redundancy to the fibre optic system should it fail.

Figure 9: Transmission equipment located on top of Peninsula Hill.

TELEPHONE EXCHANGES

Telephone exchanges (also known as digital switches) are a system of electronic components or computers that connects telephone calls so that two or more people can carry out a conversation or so that a computer can connect to a remote modem that in turn connects you to the internet etc. However, it is not as simple as turning on and off a light switch it is far more complicated than that. Exchanges contain hardware that can differentiate between telephone call and a computer connection, broadband and dial up. It also contains another important piece of technology that determines whether a telephone line is busy or whether phone has been answered. This piece of technology is known as a signalling system, it is the way the telephone exchanges talk to one another. The purpose of the signalling system is so that phone lines are not blocked if somebody is not there or if the line is busy the actual telephone call is not connected unless the phone is answered.

Telephone exchanges operate by connecting two or more digital circuits together, according to a dialed telephone number. The exchange then encodes the speech into a computer code. The computer code is created by dividing speech into 8000 time slices per second; each time slice is represented by a digital tone. The digital tones are then sent down the transmission lines to the receiving end where the reverse process occurs. In other words, when you use a telephone, you are generally having your voice "encoded" and then reconstructed for the person on the other end. Your voice is delayed in the process by a small fraction of one second.

There are three telephone exchanges in the Queenstown Lakes District; two in the Queenstown area, one in Frankton and the other in Central Queenstown near the police station on Camp Street and one in Wanaka on Brownstone Street adjacent to the Caltex petrol station. All of these exchanges operate independently and performance is reported to a network management centre in Christchurch. Network management centres monitor the performance of every telephone exchange, every optical fibre cable, every trunk main, main service within a geographical area. If any component were to fail then these centres will know instantly about the problems and have systems that can activate systems that are built in to recover near normal service as soon as possible. In the unlikely event that someone physically has to go to an exchange to change a part, that person can be dispatched to do it. The three exchanges in the Queenstown Lakes district requires power to function properly but are equipped with a battery powered back up system that can be recharged with portable generators.

ROADSIDE CABINETS & ACCESS PILLARs

Roadside cabinets and access pillars are used to split the main distribution cables that run from the exchange into smaller distribution cables the run along the street. Roadside cabinets serve up to 400 users and are generally placed in every neighbourhood or street. Access pillars only supply up to five users and are placed at every second property or in areas with a greater density of population, at every property. There are two types of cabinets and two types of pillars used by telecom in the Queenstown Lakes District. They include:

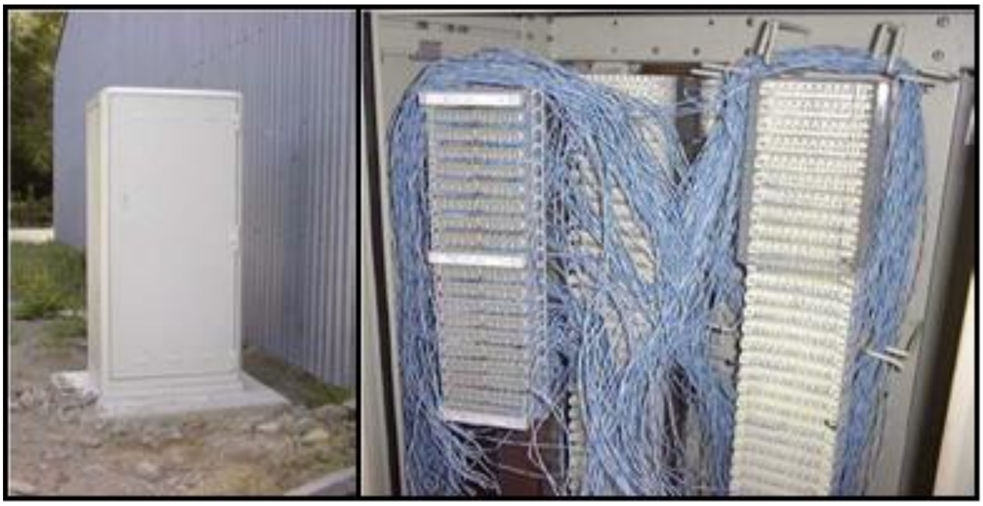


Figure 10 (Previous Page): Passive Roadside Cabinet. There generally needs to be a manhole in front of the cabinet to allow access to the ducts coming into the cabinet's base for maintenance.

- A **passive cross-connect** cabinet (figure 10) that is simply a cabinet full of connection boards for the copper cabling and does not contain electronics. These cabinets are vented to allow for natural air ventilation, removing the build up of condensation. At the cable terminal points the sheathing is removed and the connections are protected by grease. This acts as a moisture barrier, but cannot be relied upon to be waterproof.

- An **active cross-connect** cabinet. These contain electronic equipment that allows high rates of data transfer, such as broadband internet services. As technology is rolled out, customers will slowly be connected to electronic roadside cabinets. They contain batteries, which depending on the demand on the cabinet can last between 6 hours to 3 days. These cabinets contain switching equipment, which needs to be cooled by fans, and therefore the cabinets are not sealed against the outside environment.

- An **above ground** pillar (figure 11) which is vented. This type tend to be used in residential areas when there are less concerns about placing obstructions in the footpath and the distribution system tends to be cable in ground, rather than in duct.

- An **underground sealed** pillar which is sealed and waterproof. These are placed in area where obstructions in footpath would cause concern, such as retail areas, but they require a cable in duct distribution system.

Figure 11: Above ground pillars

COPPER CABLING DISTRIBUTION

The copper cabling is sheathed with a plastic coating for protection against the environment, including water penetration. Should this sheathing fail and the copper within comes into contact with water, the cables would short out and no longer function. To provide additional protection against this, the older cables are filled with compressed air between the copper and sheathing. Should the sheathing be damaged the compressed air will bubble out, and not allow the water to enter. The newer cables are filled with grease, providing a waterproof barrier.

The copper cabling distribution system is within a ducted system. This does give some further protection during flood events, but the ducts are primarily installed to allow easy installation of cabling and to provide some protection/warning to the cabling from future works within the road by others. They are not sealed and can often contain water. Telecom estimates that the majority of the cabling is of the greased type, but point out that the protection system is chosen on a case by case basis for various technical reasons.

CELLULAR TOWERS

A cell tower is simply a small low-powered radio transmitting and receiving station (figure 12). A typical cell tower consists of three to four antennas attached to a building or mast. These antennas are responsible for sending and receiving radio signals to and from cell phones. Also contained within a cell tower is a range of communication equipment including one or more sets of transmitter/receivers transceivers, digital signal processors, control electronics, a GPS receiver for timing, regular and backup electrical power sources, and sheltering. All this equipment is used to create a ‘cell’ in a mobile phone network (or cellular network).

The coverage or working range of a cell tower (the distance away a mobile phone can connect to it) is not a fixed figure. It will depend upon the technology it uses, the transmitters’ power and size, and the array setup of the panels. Geographical and meteorological conditions can also influence the range. As a rough guide, based on a tall mast and flat terrain, it is possible to communicate from up to 70 km away. When the terrain is hilly like in the Queenstown Lakes District, the maximum distance can vary from as little as 5 to 8 km. Sometimes the area is deliberately restricted as there is a limit on the number of callers a single cell tower can handle at one time. To increase the number of callers that an area can handle, either a more powerful antenna needs to be installed or another cell tower has to be built. Thus, the density of cell towers is governed by the cell phone usage in the area.

Figure 12: Cell tower in Frankton

In the Queenstown Lakes district there are a number of cell towers which provide cell phone coverage to all of the urban area and much of the surrounding rural areas (figure 13). Sites vary from hill tops to building faces and are linked to the telephone network either by microwave radio or fibre optic cable. If this link to the telephone network is broken then the cellphone transmitter/receiver cannot operate and therefore the call can not be connected and/or the message can’t be sent.

Cell phones may fail to function, because they are too far away from a mast or the user is in a location where there is interference (e.g. signal blocked due to thick building walls, hills or other structures). Signals do not always need a clear line of sight but the more interference there is the more it will degrade or eliminate reception. Another limiting factor for cell phones is the ability of the cell phone to send a signal from its low powered battery to the mast. Some cell phones perform better than others, depending on their ability to send a good signal from the phone to the mast.

The mast that a cell phone sends its signal to is chosen based on the signal it receives from the mast. For example as a user moves around the intelligence of the cellphone monitors reception and enables the phone to switch from one mast to the next during conversation. As the user moves towards a mast it picks the strongest signal and releases the mast from which the signal has become weaker and that channel on that mast becomes available to another user.

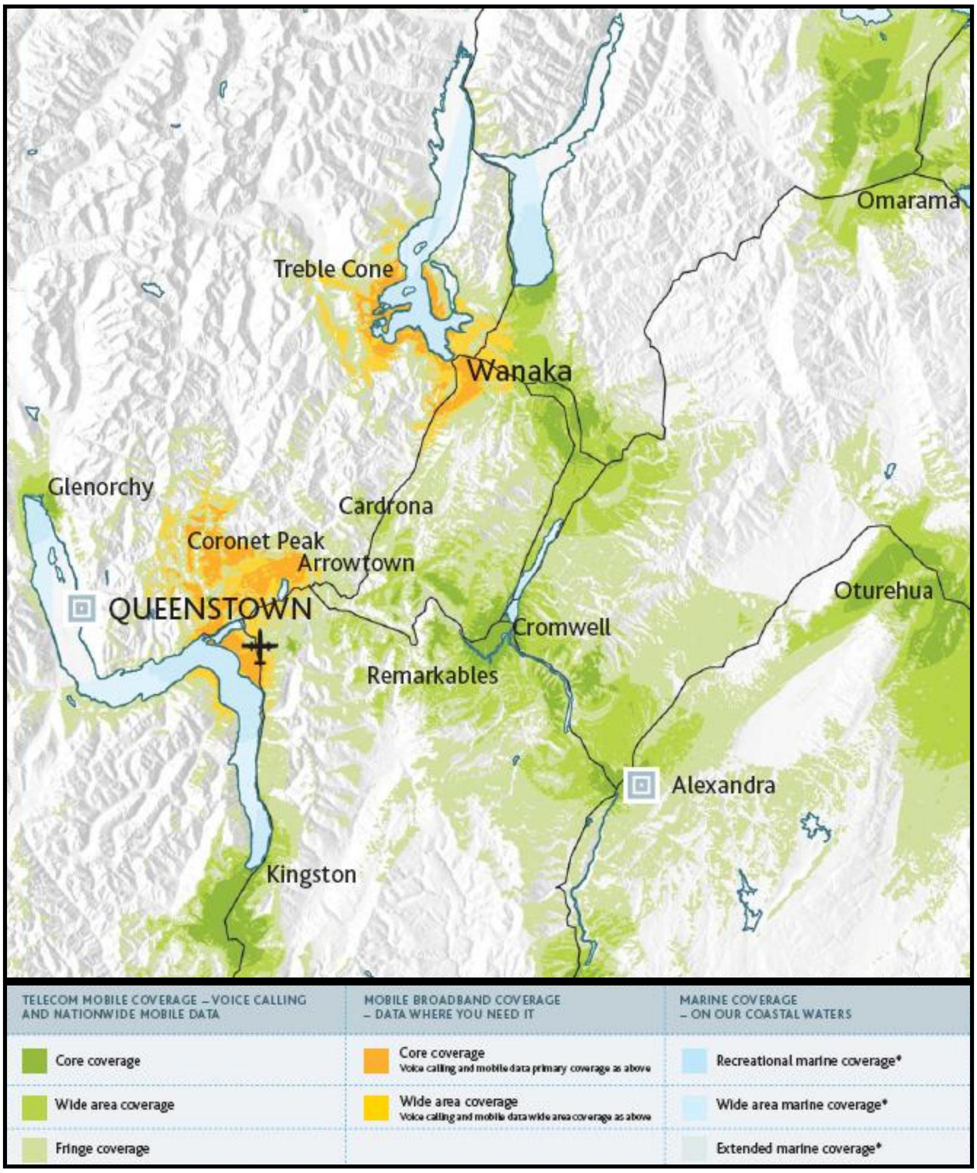


Figure 13: GIS map of cellphone coverage in the Queenstown Lakes District.

BROADCAST NETWORK

Figure 14: Components of the Broadcast Network located at the top of Peninsula Hill above Kelvin Heights

In a broadcast system such as those used for radio and television, a central high-powered broadcast tower transmits high-frequency electromagnetic waves to numerous low-powered receivers within a specified area (figure 14). The high-frequency wave sent by the tower contains a signal containing visual or audio information. The antenna (such as the one on top of a roof or one within a handheld radio) is then tuned so that it picks up the high-frequency wave and a demodulator is used to retrieve the signal containing the visual or audio information. This information is then decoded and is either displays as picture on a TV screen or sound from a radio. Broadcast systems are important as they are useful for distributing important information to a large number of people in different areas at the same time including the distribution of important information during emergencies.

TELEVISION AND RADIO BROADCAST

In the Queenstown Lakes district the signals are broadcast using a high powered broadcast tower on top of Peninsula Hill or at the end of the Kelvin Heights peninsula (figure 15). Unfortunately broadcast systems can be limited in terms of range, particularly for broadcast TV. This is because the radio signals used to broadcast television emit from the broadcast antenna in a straight line. In order to receive these signals, there has to be a direct line of sight of the antenna. Small obstacles such as trees or small buildings can distort the signal but are not generally a problem. However a large obstacle, such as a large mountain range may cause a total loss of transmission. The solution to this problem has been solved with the introduction of satellite TV. Satellite TV solves the problems of range and distortion by transmitting broadcast signals from satellites orbiting the Earth. Since satellites are in orbit, there are many more customers in the line of sight. Satellite TV systems transmit and receive radio signals using specialized antennas called satellite dishes.

UHF AND VHF RADIO COMMUNICATION

UHF and VHF radio communication is used to provide back up in the case of failure or disruption of telephone-based communication. UHF and VHF radio communication are widely used in the day to day functions of the emergency services and contractors, particularly out of range of the telephone network. During a disaster UHF and VHF radio communication will be used to co-ordinate responses between emergency services and lifeline operators from the Civil Defence Emergency Operations Centre.

Figure 15: Radio antenna located on the golf course at the end of the Peninsula

A repeater is an electronic device that receives a signal and retransmits that signal at a higher power so that the signal can cover longer distances without degradation. They are most commonly used to transmit a signal across an obstruction such as a hill. This operates in a similar fashion to a cell tower however communication is not reliant on passing through switching equipment and therefore can run on batteries without the need to be connected to electricity mains.

The primary repeater in the Queenstown Lakes District is located on top of the Remarkables and is used to communicate with the Mt Obi and Swampy repeaters. The primary purpose of these repeaters is to ensure that communication is maintained between the Civil Defence emergency operation centres, local councils and lifeline operators using radio telephones.

WATER SUPPLY

Water is a necessity for life. A person can survive several days, or even weeks, without food, but can only survive a couple of days without water. To function properly the human body needs a constant supply of water (approximately two litres daily) in order to replenish the fluids lost through everyday activities, such as respiration, sweating and urination. In the event of a disaster or other unforeseen situation, drinking water can quickly and without notice become temporarily cut-off, contaminated and unsafe to drink.

Water is not only essential for our survival it is also an important part of our daily activities. In our homes we use water for drinking, cooking, cleaning, flushing the toilet, watering the garden and washing (ourselves, our clothes, our cars and our houses). Water is used for fire fighting, irrigation, industrial and manufacturing processes. We use water in vast amounts every day. Most of us take this for granted and are not aware of the vast network of pipes and infrastructure that source, treat, store and distribute drinkable water right into our homes.

The Queenstown Lakes District has eight public water supply schemes that provide people with water. These schemes are located in Queenstown, Arrowtown, Glenorchy, Lake Hayes, Arthur's Point, Wanaka, Lake Hawea, and Luggate. Other communities in the district such as Kingston, and Makarora, do not currently have a reticulated water supply, but rely instead on private bores and rainwater collection. Water supply systems within the district can be generally broken down into four main stages; collection, storage, treatment and distribution (figure 16).

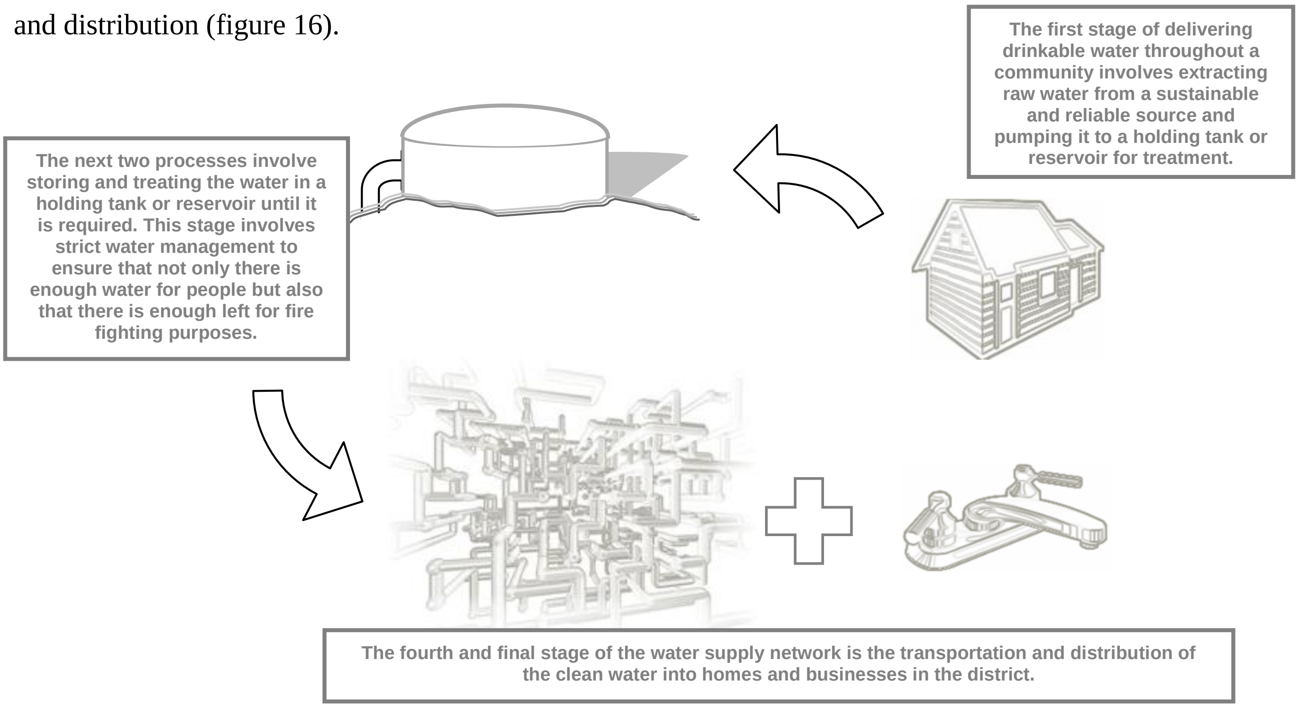


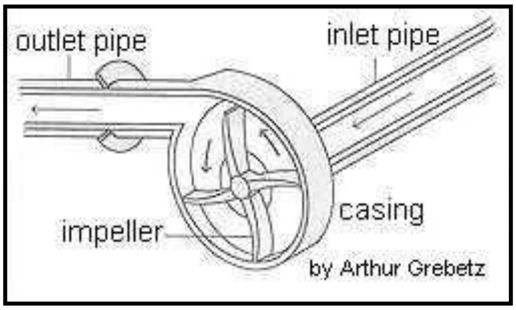
Figure 16: Systematic diagram of a general water supply system. The water supply systems in the Queenstown lakes district can be broken down into four stages; collection, supply, treatment and distribution.

WATER COLLECTION

Water in the Queenstown Lakes District is an integral part of the natural environment and has played a critical role in the development of the district. Communities within the district developed on the edges of the glacial lakes, rivers and other natural waterways because they were a good source of safe clean water.

Drinking water in the district comes from one of three sources; surface-water, groundwater or rainwater. Surface water includes water that flows down rivers and into lakes. Surface water sources are constantly replenished by water entering the system from natural springs or precipitation (rain, snow etc). Groundwater is water located beneath the ground surface in aquifers – pore spaces and fractures – in the rock capable of transporting water. Wells (also called bores) are drilled into these aquifers and the water is then pumped to the surface. Rainwater is sourced when drops of water fall to the earth's surface from clouds in the atmosphere. This rainwater or precipitation is then collected by channelling the water into storage tanks.

In the Queenstown Lakes District the large-scale water supply systems such as those used in Queenstown and Wanaka rely on surface water resources. Smaller water supply systems such as those in Arrowtown and Glenorchy tend to use groundwater resources that lie within the Wakatipu basin. Communities such as Kingston and Makarora as well as a few private residences rely on rainwater collection.



INTAKE STRUCTURES

Raw water from the environment is extracted using centrifugal pumps. These pumps are generally housed in an intake structure that contains a power supply cabinet and control valves not to mention an intake pipe that is either drilled into an underground aquifer or placed into a lake.

Centrifugal pumps work by using rotating blades, called impellers to increase the velocity of water so that it can rise to a higher level. As the water enters the pump it accelerates while passing from the centre of the impeller to the outer edge of it. As it leaves the impellers the water is collected by the surrounding casing where its velocity is converted into static pressure before leaving the pumps discharge. This outward flow reduces the pressure at the impeller eye, allowing more liquid to enter (figure 17). The water is then conveyed to a primary storage facility where it may be treated.

The control valves at the intakes act as throttling valves, and are used during a change in the pump discharges. Failure of the control valve does not mean that the intake stops operating, but it does cause the pumps to either run at full capacity, or not at all, which results in significant pump wear over time. Intake structures in the Queenstown Lakes District are not waterproof and an water ingress into these buildings may damage control valves and will disrupt power supply.

SURFACE WATER

The Queenstown Lakes District is characterised by its surface water. For centuries people and communities have used this water to provide for their social, economic and cultural well-being. The surface water in the district includes Lakes Wakatipu, Wanaka and Hawea; together they make up 22% of New Zealand's lake surface area. Water in these lakes is derived from natural springs, rain and from snowmelt that drains into catchments that are located high in the Southern Alps. The catchments are variable in size but all have reliable flows.

Figure 18: The Kevin Heights raw water intake in Lake Wakatipu. The Kelvin Heights reservoir is located directly above it.

The quality of the surface water in the district reflects the environmental conditions in which it was derived. Generally however, the water is of very good quality. The chemical determinants such as pH and alkalinity are acceptable and physical determinants such as colour and turbidity are well within the accepted norm. Organic and inorganic determinants such as colour and turbidity are also very low. The only possible parameter that is occasionally of concern is turbidity. Sometimes during a wind or storm event, bottom sediments may be disturbed. If this happens, a turbidity meter on each intake sets off alarms and the supply can be shutdown until the turbidity level has decreased to an acceptable level.

- ***Queenstown***

  The Queenstown water supply network sources its water via two raw water intakes from Lake Wakatipu, known as the Two-mile and Kelvin Heights intakes (figure 18). The Two-mile intake is located on the Eastern shore of Lake Wakatipu at Two Mile Creek and the other is located on the Kelvin Heights Peninsula on the Frankton Arm. The water is pumped from these intakes to two key reservoirs, Twin Reservoir and Kelvin Heights Reservoir (figure 19).

Figure 19: Photograph of the Kelvin Heights intake (right) and corresponding reservoir (left).

These two intakes provide a high degree of redundancy within the Queenstown water supply system; because depending on the demand of the system, should the Kelvin Heights supply not be available, the Two-Mile intake in addition to supplying its usual area would be able to supply the storage facilities which serve the Kelvin Heights area. Furthermore, should the Two-Mile intake not be available, the Kelvin Heights intake would be able to supply the storage reservoirs which serve the Queenstown area. However, if one of these scenarios were to occur it would be important to put rationing in place so that reservoirs do not run dry.

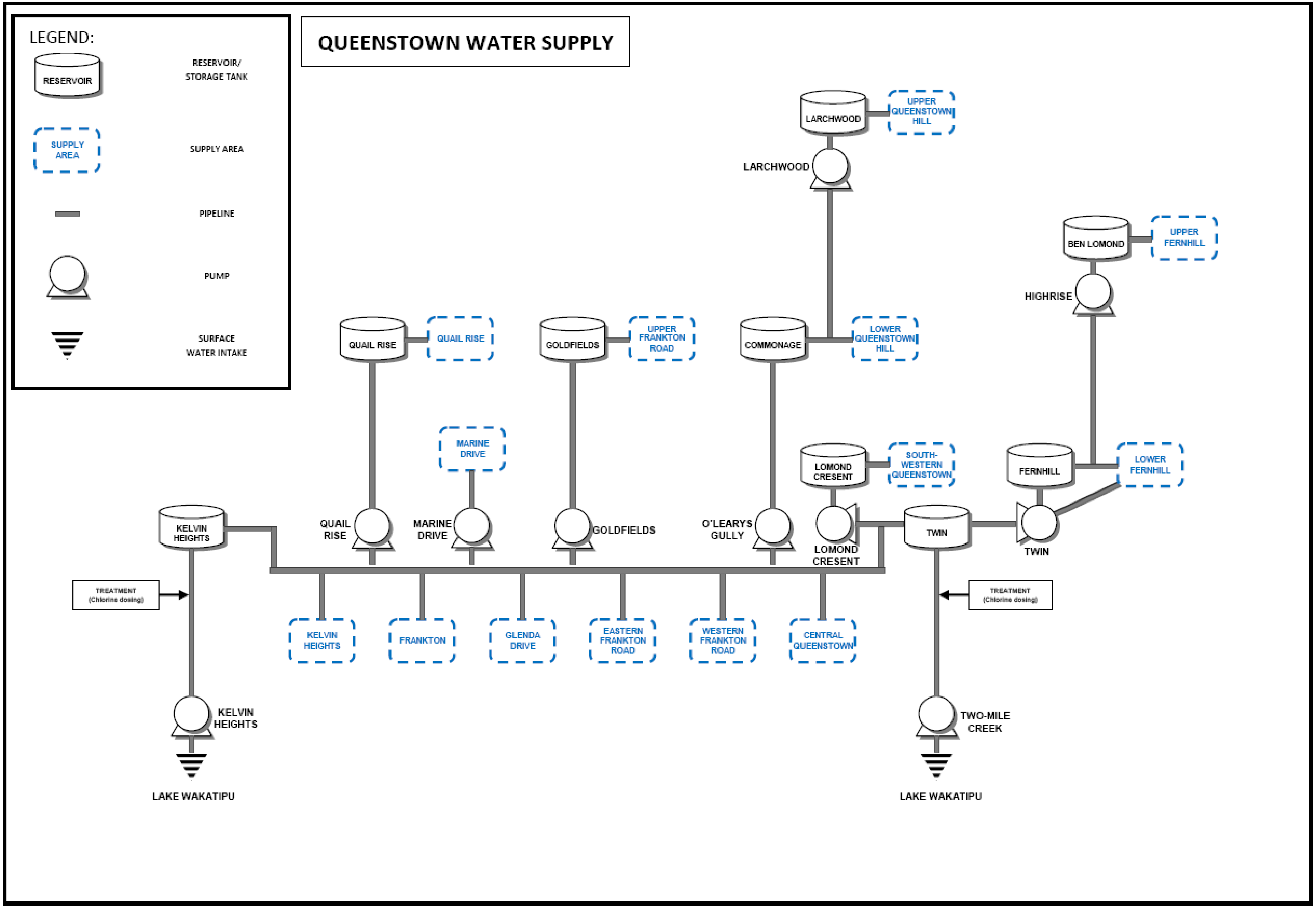
- ***Wanaka***

  The Wanaka water supply system sources water via three intakes from Lake Wanaka, known as the Roy's Bay, Western and Beacon Point intakes (figure 20). Water supplied to the area could come from any of these three intakes depending on the demands on the system at the time. However, as with Queenstown's water supply system if a water intake were to fail, strict water rationing would be needed.

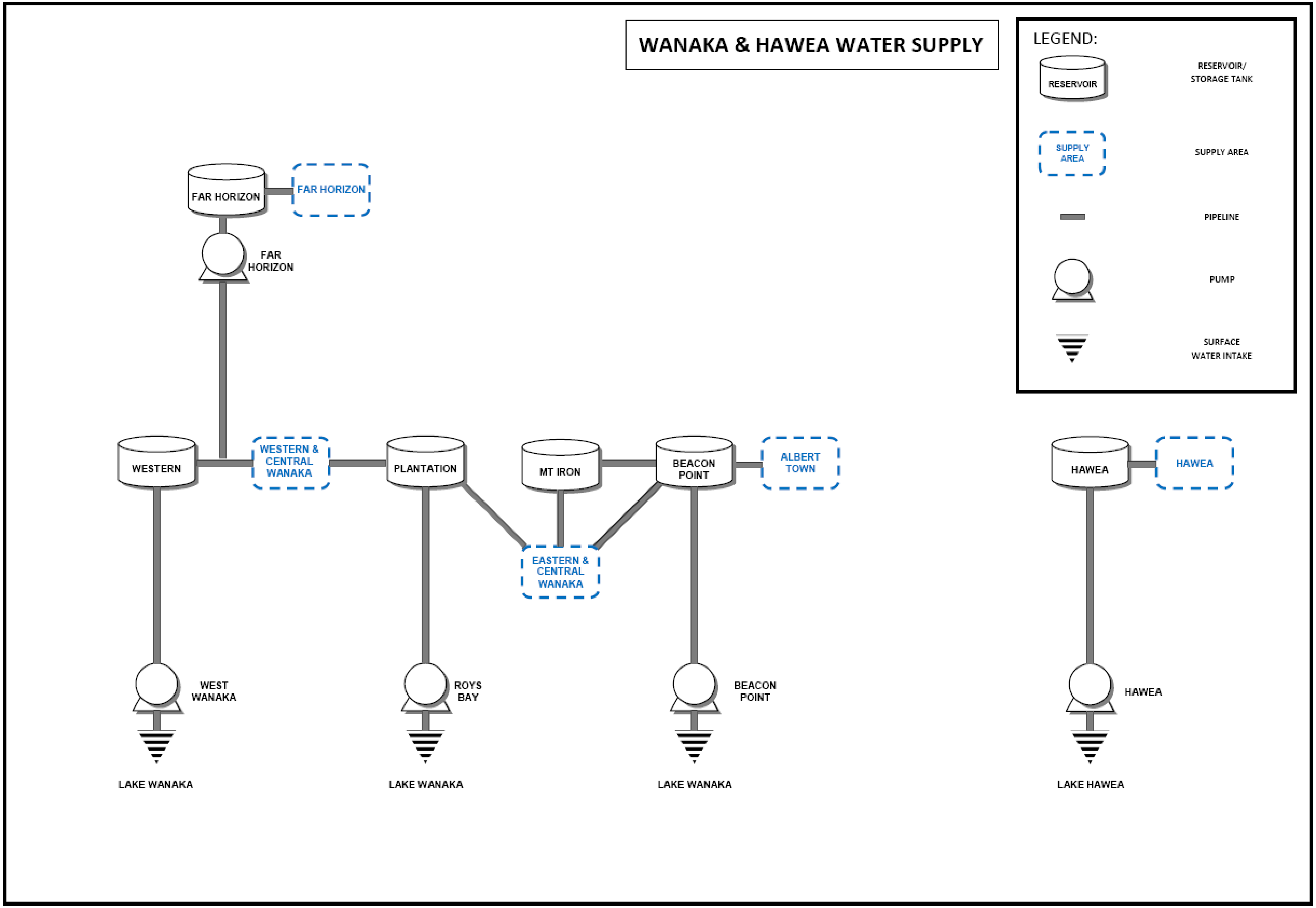
- ***Hawea***

  The township of Hawea sources all of its water from a single intake structure located by the control structure at the outlet for Lake Hawea (figure 20).

Figure 20 (Following Pages): Diagrams of community water supply systems. If a system component fails for example the O'Leary's Gully pump station, the water supply to everything that component services will be disrupted (i.e. Commonage reservoir, Larchwood reservoir and pump and supply to the entire Queenstown Hill area). Thus, this diagram illustrates the importance of components and their vulnerability.



LEGEND:
RESERVOIR
RESERVOIR/ STORAGE TANK
SUPPLY AREA
SUPPLY AREA
PIPELINE
PUMP
SURFACE WATER INTAKE
QUEENSTOWN WATER SUPPLY
LARCHWOOD
UPPER QUEENSTOWN HILL
LARCHWOOD
BEN LOMOND
UPPER FERNHILL
HIGHRISE
QUAIL RISE
QUAIL RISE
GOLDFIELDS
UPPER FRANKTON ROAD
COMMONAGE
LOWER QUEENSTOWN HILL
MARINE DRIVE
LOMOND CRESENT
SOUTH-WESTERN QUEENSTOWN
FERNHILL
LOWER FERNHILL
KELVIN HEIGHTS
QUAIL RISE
MARINE DRIVE
GOLDFIELDS
O'LEARYS GULLY
LOMOND CRESENT
TWIN
TWIN
TREATMENT (Chlorine dosing)
TREATMENT (Chlorine dosing)
KELVIN HEIGHTS
FRANKTON
GLENDA DRIVE
EASTERN FRANKTON ROAD
WESTERN FRANKTON ROAD
CENTRAL QUEENSTOWN
KELVIN HEIGHTS
TWO-MILE CREEK
LAKE WAKATIPU
LAKE WAKATIPU


WANAKA & HAWEA WATER SUPPLY
LEGEND:
RESERVOIR
RESERVOIR/ STORAGE TANK
SUPPLY AREA
SUPPLY AREA
PIPELINE
PUMP
SURFACE WATER INTAKE
FAR HORIZON
FAR HORIZON
FAR HORIZON
WESTERN
WESTERN & CENTRAL WANAKA
PLANTATION
MT IRON
BEACON POINT
ALBERT TOWN
EASTERN & CENTRAL WANAKA
HAWEA
HAWEA
WEST WANAKA
ROYS BAY
BEACON POINT
HAWEA
LAKE WANAKA
LAKE WANAKA
LAKE WANAKA
LAKE HAWEA

GROUNDWATER

Arrowtown, Lake Hayes, Arthur’s point, Glenorchy and Luggate source their drinking water from groundwater resources (figure 21). Aquifers in the region include the Wakatipu Basin Aquifer and parts of the Hawea Basin, Wanaka Basin and Cardrona Gravel Aquifers. There are also aquifers in Glenorchy and Kingston areas. Water in the aquifers is of similar quality to that of surface water; however turbidity is not as great a concern.

- ***Arrowtown***

  The Arrowtown Township and the adjacent Millbrook Resort sources its water from two bore holes located close to the Arrow River in the Bush Creek tributary. The bores extract water from a shallow free aquifer where it is pumped into two storage reservoirs at the same location.

- ***Lake Hayes***

  The water for the Lake Hayes water supply scheme is derived from a natural spring along the northern shoreline of Lake Hayes. It is then pumped via a rising main to an elevated storage reservoir.

- ***Arthurs Point***

  Arthurs Point sources all of its water from two bore holes located on the true right hand side of the Shotover River. Two associated pumps then transport the water into a single storage reservoir located above the township.

- ***Glenorchy***

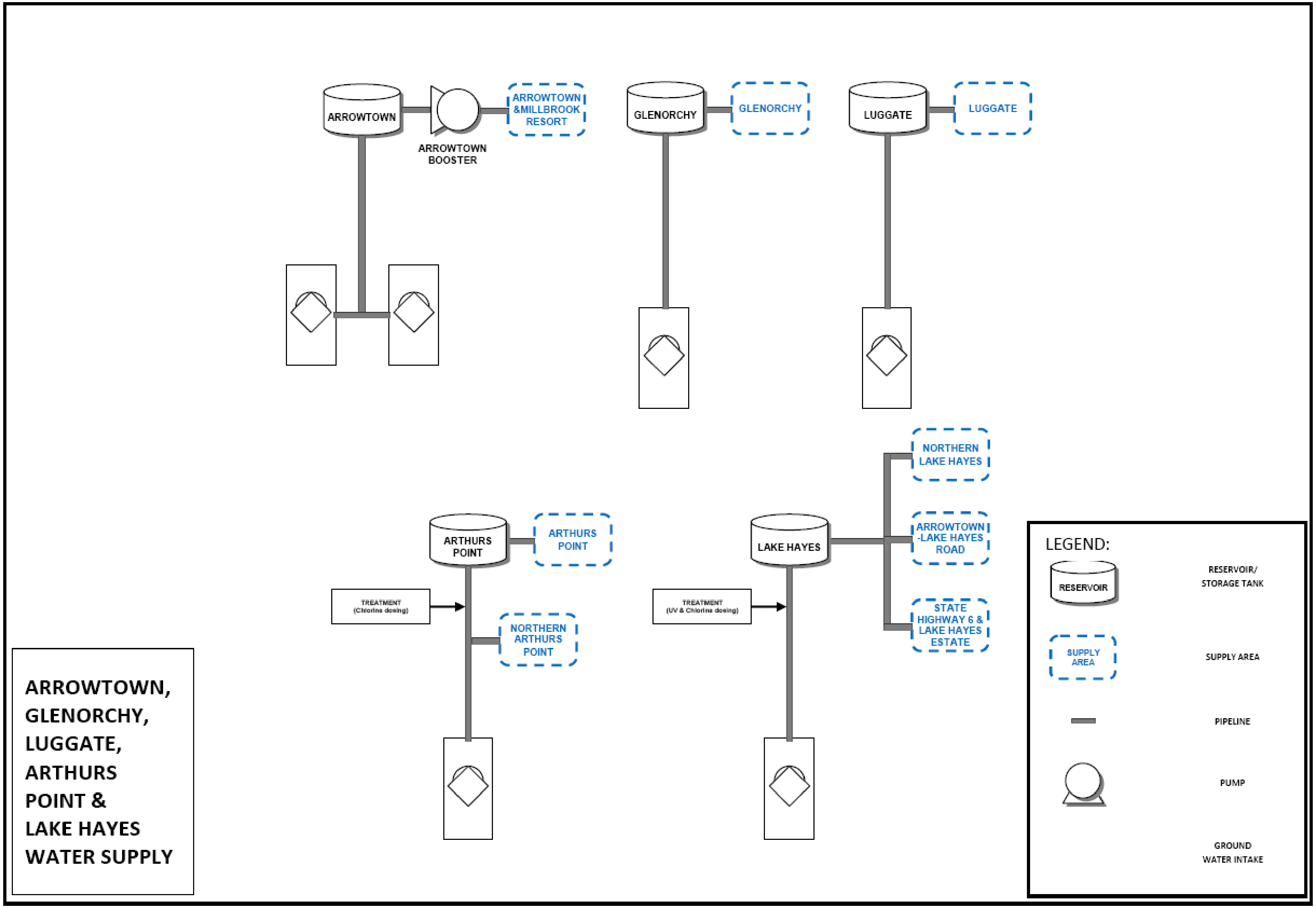
  Glenorchy’s water is sourced from two adjacent bores near Buckler Burn, south of Glenorchy. The water is pumped via one pump station to a storage tank farm.

- ***Luggate***

  The township of Luggate sources all of its water from the Luggate bore.

RAINWATER

Kingston and Makarora are among the many of the smaller communities that source their water from the atmosphere. People use rainwater tanks to collect and store rainwater runoff, typically from their rooftops via the rain gutters. Rainwater tanks may be constructed from materials such as plastic (polyethylene), concrete, and galvanized steel, as well as fibreglass which is rust and chemical-resistant. Tanks are usually installed above ground, and are usually opaque to prevent the exposure of stored water to sunlight, to avoid algal blooms. Tanks are also covered and have screen inlets to exclude insects, debris, animals and bird droppings. Tanks often come with a plastic inner lining to both increase the life of the tank and protect the water quality.


ARROWTOWN
ARROWTOWN BOOSTER
ARROWTOWN &MILLBROOK RESORT
GLENORCHY
GLENORCHY
LUGGATE
LUGGATE
ARTHURS POINT
ARTHURS POINT
TREATMENT (Chlorine dosing)
NORTHERN ARTHURS POINT
LAKE HAYES
TREATMENT (UV & Chlorine dosing)
NORTHERN LAKE HAYES
ARROWTOWN -LAKE HAYES ROAD
STATE HIGHWAY 6 & LAKE HAYES ESTATE
LEGEND:
RESERVOIR
RESERVOIR/ STORAGE TANK
SUPPLY AREA
SUPPLY AREA
PIPELINE
PUMP
GROUND WATER INTAKE
ARROWTOWN, GLENORCHY, LUGGATE, ARTHURS POINT & LAKE HAYES WATER SUPPLY

WATER STORAGE AND TREATMENT

Water treatment focuses, not only on improving the aesthetic qualities (appearance, taste and smell) of drinking water but also on contaminants that are not visible to the naked eye such as bacteria and disease-causing microbes. Today, with the increasing amount of pollutants that are released into the environment, water treatment is an important part of any urban water supply system. The Queenstown Lakes District is fortunate in that most of the water in the district is generally of very good quality before it is extracted from the environment, therefore treatment facilities in the district are very limited.

STORAGE RESIVOIRS

Storage reservoirs in the district are all located at higher elevations so that water can be distributed to communities by gravity. Taking advantage of this surrounding topography means that the water system does not have to rely on booster pump stations to distribute the water. Storage reservoirs serve an important purpose in that they have to meet variable demand in the network with constant supply of water. They also have to provide water in times of crises so must have enough reserves left for fire fighting purposes. In the district reservoirs hold fire fighting resources that will run out after about 30 minutes to 1 hr of use. Finally storage reservoirs also must hold water for a sufficient length of time so that there is enough contact time for disinfection purposes.

The optimum water levels within a reservoir are based upon the average daily consumption of water. The Queenstown Lakes District maintains a storage capacity of around 250 litres of water per person per day. During a disaster the aim is to at least have enough water to supply 10 litres of water per person per day. When the reservoir is at its maximum it should have approximately 2 days supply of water or more held within it.

- ***Queenstown***

  The Queenstown water supply system has a complex network of storage reservoirs. Once water is pumped to the two key reservoirs; Twin and Kelvin Heights reservoirs it is spread throughout another seven reservoirs with the help of six pump stations that distribute drinkable water throughout the area.

- ***Wanaka and Albert Town***

  The Wanaka and Albert town’s water supply consists of five reservoirs that provide water to the greater Wanaka area via gravity flow.

- ***Arrowtown***

  The Arrowtown water supply system comprises of two storage reservoirs that are located at the same location as the raw water intake (figure 22).

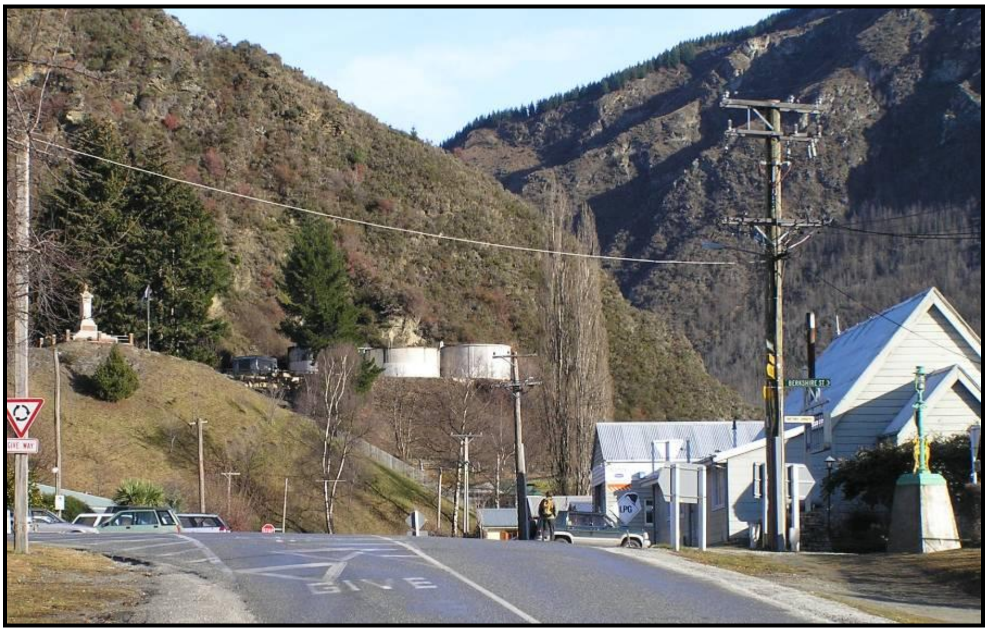


Figure 22: Storage reservoirs above the township of Arrowtown.

All the other water supply systems in the district such as the ones in Lake Hayes, Hawea, Arthurs Point and Glenorchy all consist of a single storage reservoir that supplies water throughout each community.

WATER TREATMENT

The goal of the water treatment process is to remove contaminants from untreated water to produce drinking water that is pure enough for human consumption. The first step of the water treatment process in the Queenstown Lakes District involves screening of the water when it is extracted from water sources. Screening removes floating objects (such as branches, leaves and other debris) from the water by letting the water pass through metal grills and screens.

Once the water is screened it is pumped to a water reservoir for storage and in some cases further treatment. Storage reservoirs in the district serve two purposes; firstly they are used to store water so that it can be used at a later date and secondly they aid in the water treatment process in that they enable the blending of abstracted water with water already held in the reservoir, which permits dilution of incoming contaminants. The longer storage times also allow some water quality improvements including settlement of debris and solid contaminants as well as killing some bacteria.

At a few selected storage reservoirs in the district (Kelvin Heights, and Twin reservoirs in Queenstown, Western, Plantation and Beacon Point reservoirs in Wanaka) chemical treatment in the form of chlorine dosing is also employed. Chlorine is used as a disinfectant and can be added to water as either a liquid or a gas. It is used to oxidize unwanted chemicals in the water and has an immediate anti-bacterial effect to destroy harmful micro-organisms. To ensure effective disinfection before it is sent into the distribution network the chlorine must remain in good contact with the water for a set amount of time.

Water in Arrowtown, Arthurs Point and Lake Hayes doesn't undergo any water treatment prior to reticulation, but do have chlorination facilities that can be used in emergency situations. The water supply system at Lake Hawea uses an alternative form of water treatment in the form of Ultra-violet radiation. UV treatment involves passing water through a light source that emits UV waves that inactivate harmful micro organisms. Hawea also has emergency chlorination facilities at its disposal.

RISING MAINS AND DISTRIBUTION

Water that is used for drinking is conveyed through a network of pipes, stored intermittently and pumped where necessary, in order to meet the demands and pressures in the system. The water distribution network can be subdivided into rising mains and distribution pipelines. The difference between the two can be defined by their objectives. Rising mains generally do not directly serve consumers; they are constructed for the conveyance of raw water only. They usually connect the raw water intakes to a water reservoir or treatment facility. Water distribution systems consist of a network of smaller pipes with numerous connections that supply water directly to the users. The water distribution system also supplies water to other apertures such as other reservoirs, pumping stations, water towers, hydrants and equipment that can be installed in the system. Rising mains are generally pressurised whereas distribution pipelines use gravity fed.

The overall aim for the water transport systems is to supply adequate water quantities, maintaining the water quality achieved by the water treatment process. In the Queenstown Lakes District treated water is conveyed to residences by way of a reticulated system consisting of PVC, PE and Ductile Iron piping less than 30 years old and with the majority being 100 mm in diameter. Transportation and distribution failures can affect not only customers relying on a water supply but can indirectly cause local flooding or potentially trigger landslides. The transportation and distribution networks may fail if pipelines are damaged, causing supply to stop.

- ***Queenstown***

  The Queenstown water supply is a complex system that supplies the Kelvin Heights, Quail Rise, Fernhill, Sunshine Bay, Frankton, Frankton Road and Queenstown areas. Treated water is conveyed to residences by way of a closed and pressurised reticulated system consisting of water mains, booster pump stations and laterals.

- ***Arrowtown***

  The Arrowtown water supply system conveys water to the entire Arrowtown Township as well as providing water to the adjacent Millbrook Resort under a supply contract.

- ***Lake Hayes***

  Water is conveyed to the Lake Hayes community via gravity. Water is provided not only to properties within the Lake Hayes estate, but is also provided to properties north of Lake Hayes, along Arrowtown-Lake Hayes road and State Highway 6.

- ***Hawea***

  The Hawea water supply system is limited to supplying the Hawea Township and adjacent rural residential areas.

The Arthurs Point, Glenorchy and Luggate water supply systems supply the Arthurs Point, Glenorchy and Luggate townships respectively. Parts of Glenorchy remain unreticulated and these properties have to source their water from private bores or rainwater collection systems.

WASTEWATER

Wastewater is used water or any other water that has been adversely affected in quality by contaminants. Contaminants can arise from a number of sources and can come about in a variety of forms and a range of concentrations. Wastewater is the waste from our homes and workplaces and includes excess water that collects on car parks, roads, buildings, driveways and gardens. Any water that is even slightly contaminated is termed wastewater.

Wastewater is typically made up of 99% water and only 1% contaminants. Common contaminants may include; organic matter such as human waste and food scraps, soaps, oil and grease, traces of heavy metals such as silver, lead, zinc and copper, debris such as sand, grit, wood and plastic, bacteria and viruses that can make people ill, harmful nutrients such as nitrogen and phosphorus that can result in toxic algal blooms that cause excessive plant growth and can cause marine life to die and dangerous toxic chemicals. Much of the water found within wastewater systems is purposely added in order to transport the waste to the pump stations or treatment facilities. The rest of the water is derived from the atmosphere in the form of precipitation or is excess water from a tap or hose.

In the Queenstown Lakes District the wastewater system is divided into two totally separate networks; the stormwater network and the sewerage network (figure 23).

Figure 23: Diagram illustrating the difference between wastewater and sewage system

1. Stormwater is excess water that runs over the ground on its way to the sea. When rain falls on a car park, a building, a road, a driveway or a garden it follows a natural flow path or is collected by a pipe system where it flows downhill until it reaches a natural waterway, such as a river, stream or lake. Stormwater not managed correctly can cause severe damage to the natural and built environment.

2. Sewage generally comprises of liquid waste produced by humans that typically consists of washing water, faeces, urine, laundry waste and other material which goes down drains and toilets from households and industry. It is a major source of pollution especially in densely populated areas and therefore needs to be managed and treated before it is disposed back into the environment.

Stormwater and sewerage must be able to run separately to each other, and it is considered illegal to connect the two systems. For example sewerage systems should only be connected to drains such as sinks, toilets, showers and other white-ware. If sewerage systems were to be connected to stormwater drains such as roof guttering or street culverts, pump stations will be unable to cope with the excess water and sewage is likely to overflow onto the streets. The same applies to stormwater systems. Stormwater systems should only be connected to roof guttering and storm culverts, otherwise if sewage were to be added into the stormwater system it would result in the untreated water entering the lakes and rivers of the district. It is important to note that we collect drinking water from these rivers and lakes and if they become contaminated with sewage, people would become extremely ill.

STORMWATER NETWORK

Figure 24: Picture of a stormwater drain.

Stormwater is excess water that runs over the ground on its way to the sea. Stormwater generally originates during precipitation events such as heavy rainfalls and snowfalls however excess water from the garden hose or an irrigation scheme may also contribute to the system. Stormwater that does not soak into the ground becomes surface runoff, which either flows into natural waterways such as rivers or streams or is channelised into storm sewers. For example when rain falls onto a roof it is collected by the guttering and transported into an underground drain through a system of pipes. This is the same as when rain falls on an impervious surface such as a road; it is channelised into a culvert and then transported via gravity to the same underground drain. This drain then carries all the water directly to a stream or other natural waterway.

In the Queenstown Lakes District there are stormwater systems located in Queenstown, Wanaka, Hawea, Albert Town, Arrowtown, Glenorchy, Arthur's Point and Lake Hayes. Other settlements in the district such as Kingston, Luggate and Makarora have limited stormwater infrastructure and typically rely on ground soakage and natural watercourses for their stormwater removal. In addition to the public stormwater systems located in the townships there are also a number of rural stormwater systems scattered around the district that consist of open channels.

Stormwater systems in the district typically comprise of street culverts, pipelines and open channels. This stormwater infrastructure is laid down at a downward angle so that the stormwater can flow under the influence of gravity, downhill, until it is discharged directly into a natural waterway such as a river or lake. This eliminates the need for pumping stations to remove the excess stormwater. Along with the absence of stormwater pumping stations there are also no stormwater treatment facilities anywhere in the Queenstown Lakes District. For this reason it is extremely important that sewage systems such as sinks, toilets, showers and other white ware are not connected to the stormwater network as any materials that are deposited into stormwater drains will end up in our natural waterways such as our pristine lakes; which are coincidently also our source of our drinking water.

Most of the piped stormwater network is underground and the only recognisable sign that this infrastructure actually exists are the manhole covers and grates alongside the roads that lead into it. The entire stormwater reticulation network within the Queenstown Lakes District consists predominantly of uPVC or concrete piping, less than 40 years old and the majority being 200 - 300mm in diameter. It is important to note that natural streams and open stormwater channels also play an important role in stormwater management.

Stormwater in Queenstown is discharged into Lake Wakatipu. In Wanaka stormwater is drained into either Lake Wanaka or the Cardrona River. In Hawea and Albert Town stormwater is drained into Lake Hawea or the Clutha River. Arrowtown's stormwater drains into the Arrow River. Glenorchy's stormwater infrastructure only consists of open water courses and some culverts, stormwater discharges into Lake Wakatipu. Arthur's Point stormwater infrastructure also consists only of water courses and some culverts; stormwater discharges into the Shotover River.

SEWERAGE NETWORK

The modern sewer system is an engineering marvel. Homes, businesses, industries, and institutions throughout the Queenstown Lakes District are connected to a network of below-ground pipes which transport sewage to treatment plants where biological physical, chemical and mechanical techniques are used to treat the sewage before it is released back into the environment. Each day approximately 60 million litres of sewage is removed from homes, shops, and business premises in the Queenstown Lakes District. The wastewater is conveyed through approximately 300km of sewer mains and pipes through numerous pumps, screens and channels. We seldom give a thought to where all the wastewater goes let alone how it actually gets there.

The removal and proper treatment of sewage is important in the response to a disaster because, if not managed correctly, sewage can cause outbreaks of life threatening diseases to spread throughout the region. Sewage can not only increase the risk to humans but can also cause adverse effects to the environment.

The Queenstown Lakes District has seven public reticulated sewage systems located in Queenstown, Wanaka, Hawea, Albert Town, Arrowtown, Arthur's Point and Lake Hayes. Other settlements in the District such as Glenorchy, Kingston, Luggate and Makarora have limited sewage infrastructure and typically rely on individual septic tanks, package treatment plants and private community schemes for sewerage treatment. The sewage system in the district can be broken down into three main components as illustrated in the following diagram (figure 25).

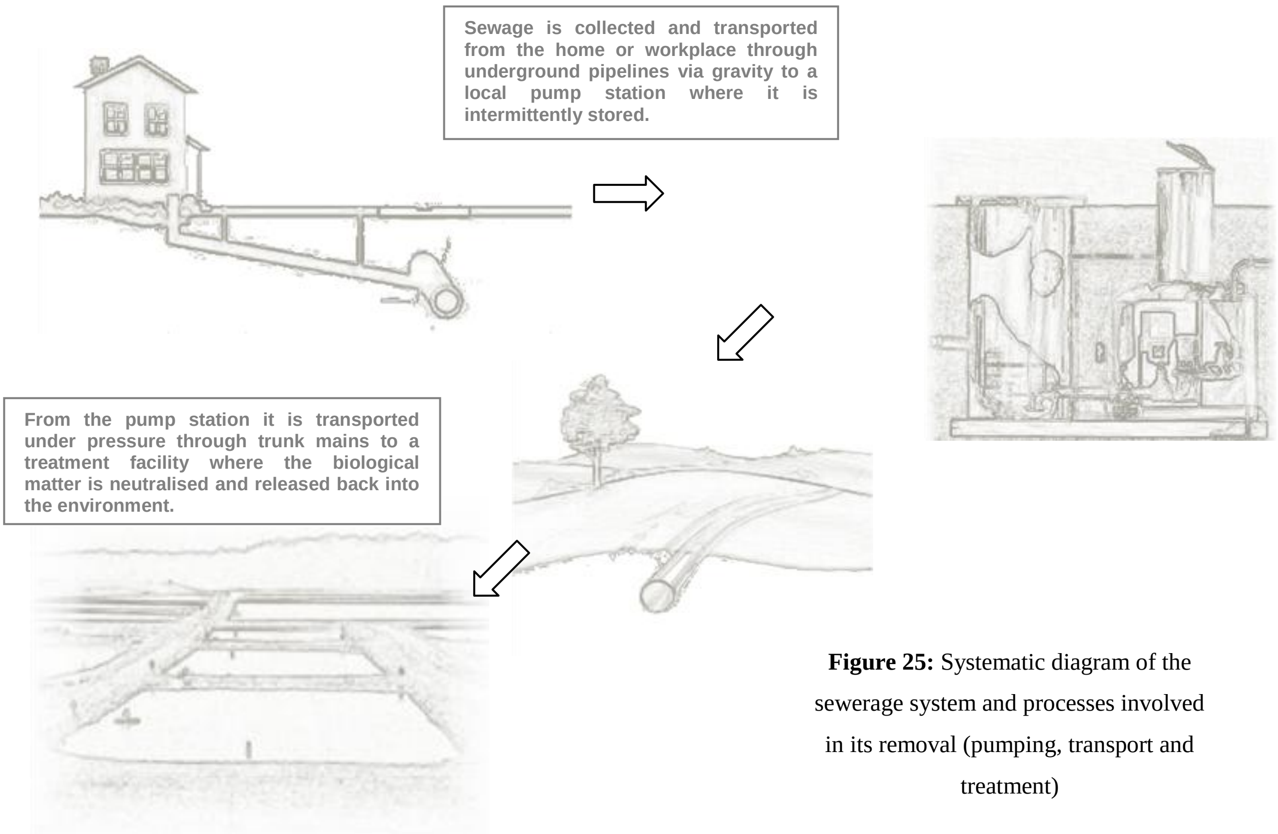


Figure 25: Systematic diagram of the sewerage system and processes involved in its removal (pumping, transport and treatment)

PUMPING STATIONS

Pumping stations within the Queenstown Lakes District collect raw sewage from a network of underground gravity pipelines. These pipelines are generally laid down at a downward angle so that the sewage can drain directly into the pump station from the source under the influence of gravity. After sewage is fed into a pump station it is stored in an underground pit commonly known as a wet well. The well consists of two pumps as well as a variety of electrical instrumentation that detect the rising level of sewage in the well. When the sewage level rises to a predetermined point one of the two pumps will begin pumping, sending the sewage through a pressurised pipe system to the treatment facility. The raw sewage may need to travel through a series of pump stations in order to reach the treatment facility.

During times of high flows, flooding or wet weather a single pump may be insufficient to pump the raw sewage out of the pumping station. If this is the case then (depending on the pump station) a secondary pump will start, however if pumping is still inadequate, or if the pump fails, a sewer overflow can occur, involving discharge of raw sewage into the environment.

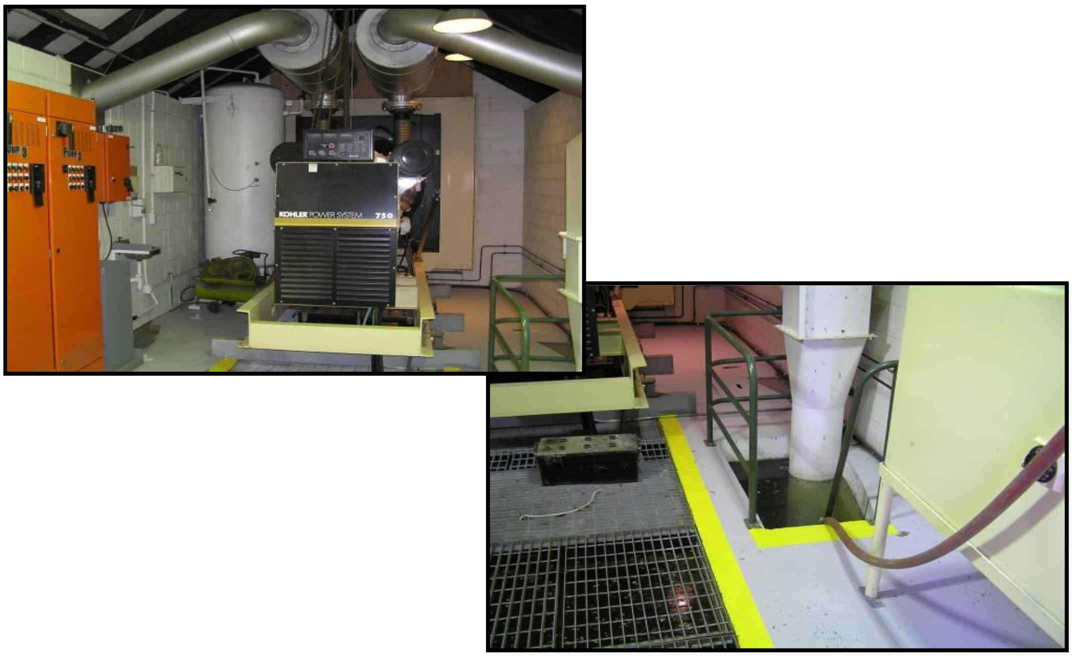
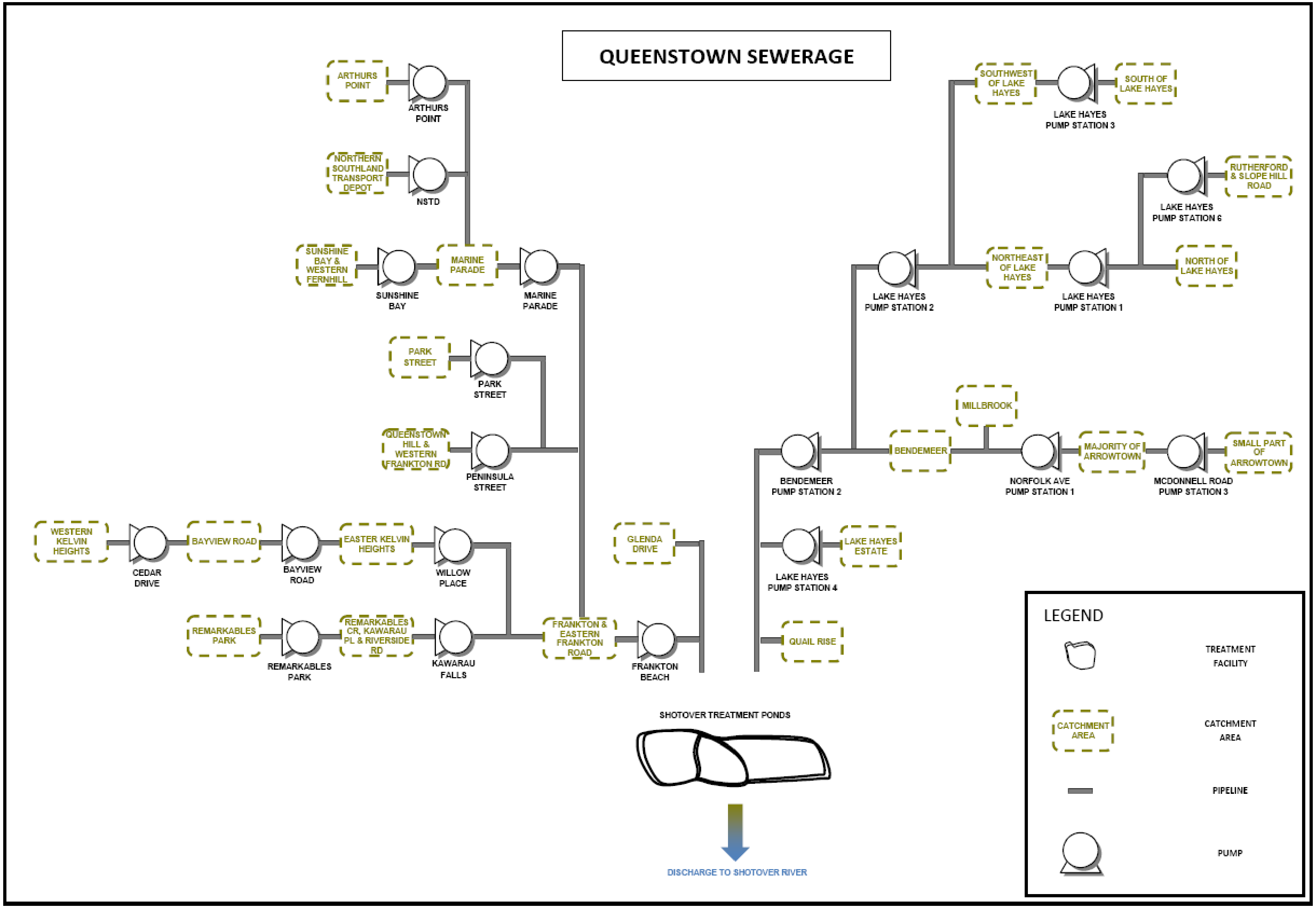


Figure 26: Picture of the Frankton Beach sewage pump station. The picture on the left shows the pump and control cabinets. The picture on the right shows the wetwell where the sewage is held before it is pumped to the treatment facility, this pit is approximately 3m deep.

The interior of a sewage pump station (figure 26) is a very dangerous place. Poisonous gases such as methane and hydrogen sulfide can accumulate in the wet well and an ill-equipped person entering the well could be overcome by fumes very quickly. To minimize the need for entry into the wetwell many facilities are designed to allow pumps and other equipment to be removed from outside the wetwell.


QUEENSTOWN SEWERAGE
ARTHURS POINT
ARTHURS POINT
NORTHERN SOUTHLAND TRANSPORT DEPOT
NSTD
SUNSHINE BAY & WESTERN FERNHILL
SUNSHINE BAY
MARINE PARADE
MARINE PARADE
PARK STREET
PARK STREET
QUEENSTOWN HILL & WESTERN FRANKTON RD
PENINSULA STREET
WESTERN KELVIN HEIGHTS
CEDAR DRIVE
BAYVIEW ROAD
BAYVIEW ROAD
EASTER KELVIN HEIGHTS
WILLOW PLACE
REMARKABLES PARK
REMARKABLES PARK
REMARKABLES CR, KAWARAU PL & RIVERSIDE RD
KAWARAU FALLS
FRANKTON & EASTERN FRANKTON ROAD
GLENDA DRIVE
FRANKTON BEACH
SOUTHWEST OF LAKE HAYES
SOUTH OF LAKE HAYES
LAKE HAYES PUMP STATION 3
RUTHERFORD & SLOPE HILL ROAD
LAKE HAYES PUMP STATION 6
LAKE HAYES PUMP STATION 2
NORTHEAST OF LAKE HAYES
LAKE HAYES PUMP STATION 1
NORTH OF LAKE HAYES
MILLBROOK
BENDEMEER
MAJORITY OF ARROWTOWN
SMALL PART OF ARROWTOWN
BENDEMEER PUMP STATION 2
NORFOLK AVE PUMP STATION 1
MCDONNELL ROAD PUMP STATION 3
LAKE HAYES PUMP STATION 4
LAKE HAYES ESTATE
QUAIL RISE
SHOTOVER TREATMENT PONDS
DISCHARGE TO SHOTOVER RIVER
LEGEND
TREATMENT FACILITY
CATCHMENT AREA
CATCHMENT AREA
PIPELINE
PUMP

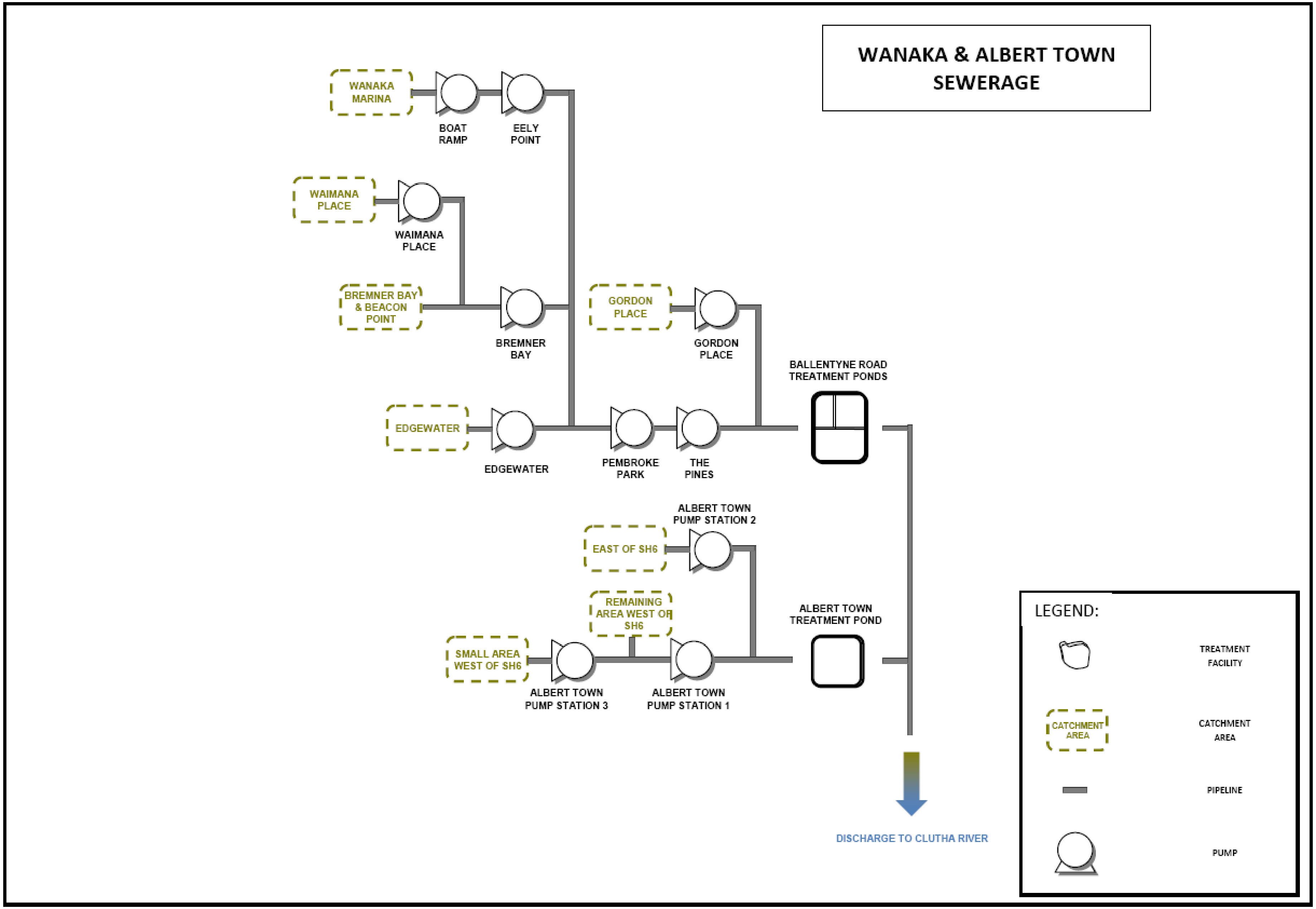

WANAKA & ALBERT TOWN SEWERAGE
WANAKA MARINA
BOAT RAMP
EELY POINT
WAIMANA PLACE
WAIMANA PLACE
BREMNER BAY & BEACON POINT
BREMNER BAY
GORDON PLACE
GORDON PLACE
BALLENTYNE ROAD TREATMENT PONDS
EDGEWATER
EDGEWATER
PEMBROKE PARK
THE PINES
ALBERT TOWN PUMP STATION 2
EAST OF SH6
REMAINING AREA WEST OF SH6
ALBERT TOWN TREATMENT POND
SMALL AREA WEST OF SH6
ALBERT TOWN PUMP STATION 3
ALBERT TOWN PUMP STATION 1
DISCHARGE TO CLUTHA RIVER
LEGEND:
TREATMENT FACILITY
CATCHMENT AREA
CATCHMENT AREA
PIPELINE
PUMP

Figure 27 (previous pages): Diagrams of sewage systems. If a system component fails for example the Pines pump station, then everything that component services will be disrupted (i.e. Brenmer Bay, Beacon Point and Edgewater). Thus, this diagram illustrates the importance of components and their vulnerability.

- ***Queenstown and Arthurs Point***

  The sewage system in Queenstown conveys sewage from thirteen catchment areas through the use of eleven pump stations that are located throughout the Arthurs Point, Kelvin Heights, Fernhill, Sunshine Bay, Frankton, Glenda Drive, Quail Rise and central Queenstown areas. The pumping stations eventually convey all the sewage to the Shotover sewage treatment facilities. However before sewage reaches the oxidation ponds for treatment they pass through two key pumping stations and a number of smaller ones. The following diagram shows sewage conveyance from start to finish.

  Many of the pump stations consist of a single submergible pump in an underground wetwell that conveys sewage to either the Marine Parade or the Frankton Beach pumping stations. The Marine Parade and Frankton beach pumping stations are generally larger than other pump stations and critical infrastructure. Together these two key pump stations are crucial for removing the sewage from Queenstown and if any one of these pumps were to fail the implications could be catastrophic.

  The Marine Parade pump station receives sewage from most of central and western Queenstown along with Fernhill, Sunshine Bay and Arthurs Point areas. It is located at the south end of Earl Street along the water front and consists of a concrete masonry building adjacent to an underground wet-well with submersible pumps and sealed steel plate covers. The operation building houses the power supply, control cabinets and emergency generator and can be accessed by both a door from the street and a roof hatch. The sewage is then conveyed to the Frankton Beach pump station.

  The Frankton Beach pump station conveys sewage from the entire Queenstown area with the exception of Quail Rise and the Glenda Drive industrial area. It is located on the Beach at Frankton along Lake Ave and consists of a sealed underground wet-well with externally connected pumps in an adjacent drywall. The pump station power supply, generator and controls are in a masonry building over the drywall. The functionality of this pump station directly affects the ability of the Queenstown area to maintain its sewage network.

- ***Arrowtown and Lake Hayes***

  The sewage system in Arrowtown and Lake Hayes conveys sewage from four catchment areas through the use of three pump stations that are located throughout the Arrowtown and Lake Hayes Areas. The pumping stations eventually convey all the sewage to the Shotover oxidation ponds. The Arrowtown pump station receives sewage from the majority of Arrowtown and McDonnell Rd. It is located along Norfolk Street and conveys the sewage to the Bendemeer pump station. Along with Arrowtown's sewage, the Bendemeer pumping station receives sewage From the Lake Hayes area as well as the sewage from the Millbrook Resort. All the sewage is then conveyed to the Shotover oxidation ponds, which is where all treatment of Arrowtown's wastewater is carried out.

- ***Wanaka***

  The sewage system in Wanaka conveys sewage from eight catchment areas through the use of eight pump stations that are located throughout the Beacon Point and Wanaka areas. The pumping stations eventually convey all the sewage to the oxidation ponds on Ballentyne Road. The Pembroke Park pump station is located to the west of the Wanaka central business district within 30 meters of the shoreline of Lake Wanaka. It consists of a concrete masonry building adjacent to an underground wet-well with submersible pumps and sealed steel plate covers. A generator has been installed to provide power in the event of regional or local power loss. It is the first of two pump stations that convey flows from the CBD area and the northern and eastern portions of Wanaka to the treatment ponds on Ballentyne Road. Wastewater from the Pembroke Park pump station is pumped to the pines pumping station.

Figure 28: Typical Queenstown Lakes District sewerage pump station. Pump station consists of a submersible pump located at the bottom of a wet well (right) with an outside transformer (left). This pump station serves a much smaller area than the larger pump station as seen at Frankton Beach (figure 26)

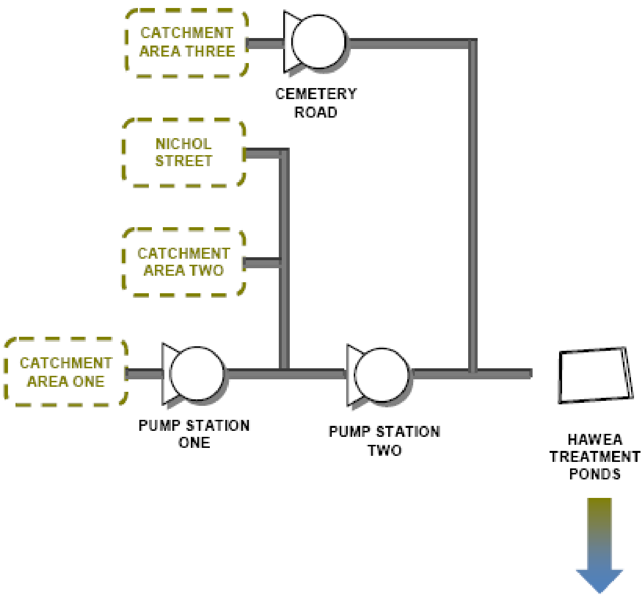
The Pines pump station is the second of the two pump stations that convey sewage to the Ballentyne Road treatment ponds. The pump station itself does not have a particular catchment area but conveys flows from the Pembroke Park pumping station to the treatment facilities out on Ballentyne Road. The functionality of this pump station directly affects the ability of Wanaka to maintain its sewage system. A generator has been installed to provide power in the event of regional or local power loss. The Gordon Place pumping station receives sewage from a small area in Southeast Wanaka and pumps it directly to the gravity main that feeds into the ponds on Ballantyne Road.

- ***Albert Town***

  The sewage system at Albert Town conveys sewage from four catchment areas through the use of three pump stations; aptly named pump stations one, two and three. Pumping station one is one of two pump stations that receives sewage from the majority of Albert town, west of SH6. Pump station three is the second pump station that receives sewage from the west part of Albert town and then conveys it too pump station one. Albert Town east of SH6 sends its sewage too pumping station two. These three pumping stations eventually convey all the sewage to the gravity pipe that leads to the Albert Town treatment ponds.

- ***Hawea***

  The sewage system in Hawea conveys sewage from four catchment areas throughout the Hawea region with the use of three pump stations, plus one private catchment and pump station. The pumping stations eventually convey all the sewage to a treatment facility located approximately 2km south of the residential area, between Domain Road and the Hawea River.



SEWAGE TREATMENT

Sewage treatment is the process of removing contaminants from wastewater. It uses physical and biological processes to produce water and solid waste or sludge that is suitable for discharge or reuse back into the environment. Sewage produced within the Queenstown Lakes District is generally collected and transported via a network of pipes and pump stations to a municipal treatment plant. Other areas in the district not connected to the council wastewater system usually use private septic tanks.

In Queenstown Lakes District sewage treatment generally involves two stages which remove approximately 90% of the contaminants, called primary and secondary stages. During these two stages the solids are first separated from the wastewater, then the remaining dissolved biological matter which is progressively converted into a solid mass by using indigenous, water-borne bacteria. There is also a third stage or tertiary sewage treatment available in which the biological solids are neutralized then disposed of or re-used, and the treated water disinfected by chemicals. However, no treatment facility in the district currently employees this process. The final effluent is discharged into a stream, river, or lake.

Primary treatment removes the materials that can be easily collected from the raw wastewater and disposed of in landfills. The typical materials that are removed during primary treatment include fats, oils, and greases (also referred to as FOG), sand, gravels and rocks (also referred to as grit) and larger settleable or floatable materials that are deposited in the sewer system, such as human waste - rags, sticks, condoms, sanitary towels, tampons, cans and fruit etc. The first materials to be removed from the sewage are the larger settleable or floatable materials. These materials are removed using a mechanical screen (milli-screen) which blocks the solid materials from passing into the next stage, sometimes this stage is referred to as the pre-treatment stage.

The remaining wastewater is then transported into oxidation ponds where Grit and FOG is removed by allowing the materials to either sink to the bottom of a basin (settle) or float on the top of the water in which the materials are later removed. Mechanical aerators that introduce oxygen into the treatment process are used to make the water less dense, causing the grit to settle out more rapidly. This process of adding oxygen into the water is also used in the secondary treatment stage.

Secondary treatment is designed to substantially degrade the biological content of the sewage that is derived from human waste, food waste, soaps and detergent. This process uses bacteria to consume biodegradable soluble organic contaminants. For this process to be effective the biota, require both oxygen and a substrate on which to live. Mechanical aerators are used in this process to introduce oxygen into the treatment process which is used to sustain the bacteria that consume the pollutants. For effective neutralisation of contaminants sewage must remain in the ponds for 30 days or more.

A private septic tank is simply a big concrete or steel tank that is buried in the yard. Wastewater flows into the tank at one end and leaves the tank at the other. Similarly to the secondary treatment stage bacteria breaks down the organic material in the wastewater before being expelled back into the environment. A septic system is normally powered by nothing but gravity.

Shotover Treatment

The Shotover Oxidation Ponds are located to the east of Frankton, between State Highway 6 and the northern end of the Remarkables, beside the Shotover River. The Shotover ponds' not only provide treatment to sewage from Queenstown but also provide treatment to sewage derived from Arthurs Point, Arrowtown, Lake Hayes and the Millbrook Resort. The Shotover Ponds consists of an inlet milli-screen, sludge digester and three treatment ponds; the two primary ponds each have aerators installed. The final pond discharges under gravity to the lower Shotover River.

Figure 30: Shotover Treatment Ponds (Source: Google Earth)

Wanaka Treatment

The Wanaka sewage treatment ponds are located along Ballantyne Road. This facility consists of three ponds with a total of twelve aerators installed to augment the natural aeration. The outfall from the Wanaka Oxidation Ponds on Ballantyne Road has a combined outfall with the Albert Town Oxidation Ponds. This outfall discharges into the Clutha River near the confluence of the

Figure 31: Wanaka Treatment Ponds (Source: Google Earth)

Cardrona River.

Figure 32: Albert Town treatment pond (Source: Google Earth)

Albert Town Treatment

The Albert Town Pond Sewage Treatment Plant consists of one pond with a single aerator. The discharge from the ponds is combined with the Ballantyne Road Ponds discharge and passed through an outflow to the Clutha River. The Albert Town oxidation pond is located to the south of the Albert Town township, located between the Albert Town – Lake Hawea Road and the Cardrona River.

TRUNK MAINS AND RETICULATION

The sewage reticulation network can be subdivided into trunk mains and reticulation pipelines. The function of the two different pipelines is similar. The only difference is that trunk mains are generally pressurised and the reticulation system is gravity fed. Once the sewage is introduced into the system the sewage flows under the influence of gravity through reticulation pipelines into a pump station. The pump station then pumps the materials to either another pump station or the treatment facility. Sewage is transported through this part of the system within the trunk mains. Trunk mains generally have a larger capacity as it transports sewage from a larger area. Therefore the diameter of trunk pipelines is generally larger.

Pipelines in the Queenstown Lakes District vary in size from 100 and 300mm (the majority however having a diameter of 150mm). The pipelines in the district are made from either PVC, uPVC, AC, concrete, or Earthenware piping of varying ages all of which are less than 40 years old.

- ***The Queenstown CBD Bypass Line***

  The Queenstown CBD is served by a fibreglass reinforced pipe lined with concrete that runs along the water front. This pipeline conveys sewage from many businesses in the CBD area as well as flow from Fernhill, Sunshine Bay and Western Queenstown to the Marine Parade pump station where it is pumped to the Frankton gravity main. As a mitigation measure to the flooding hazard that exists in the district a secondary gravity main was installed to allow sewage flow from Fernhill, Sunshine Bay and Western Queenstown to be conveyed directly to the marine parade pump station while closing off the gravity main serving the CBD area. This limits the ingress of floodwater into the marine parade pump station and allows it to function properly should the CBD become flooded.

This bypass is operated manually via a valve near the intersection of Shotover and Beech streets and a valve at the marine parade pump station. There are valves also on the existing gravity main on Earl Street that will also need to be closed should that line be inundated. In addition to this bypass, a shut-off valve on the Earl Street gravity main has also been installed at its connection to the marine parade pump station. This is a smaller gravity main servicing the Gorge Road and Stanley Street area and it is susceptible to inundation from Home Creek. The properties isolated from the foul sewer system would mean that the businesses would have to close, however it is unlikely they would still be open as inundation would be imminent.

- ***Wanaka Sluice Valves***

  To mitigate the effects of flood inundation, manual sluice valves have been installed on approximately 60-80 service laterals running from the commercial buildings along Ardmore Street to the main. These valves can be closed to prevent floodwater from entering the foul sewer system via gully traps, toilet facilities, showers and sinks in these commercial properties. This allows the existing main along Ardmore Street to convey flow from Bremner Bay, Beacon Point and other points north of the city centre to Pembroke Park pump station while minimising the ingress of floodwater from the CBD area.

  However there are doubts regarding the effectiveness of these recently installed manual sluice valves because for these valves to be effective, they will need to be closed before Ardmore Street is inundated with flood water. This will require the co-operation of all the business owners in the CBD to close the valves, hence their business, at least one day in advance (so that officials have time to locate the valves and complete their other flood mitigation duties). Business owners have said that they are reluctant to the idea as they wish to continue trading until the last possible time.

TRANSPORTATION

Transportation is the movement of people and goods from one location to another. Over time, transportation routes have become far more extensive providing greater access to townships by providing a range of alternative routes. Together with the fact that vehicles have become far more reliable the transportation network has greatly influenced where people live and as a result, populations have expanded away from main city centres and many people, now live comfortably in more remote isolated areas away from manufactures and industry. Small urban communities that are located away from main city centres like those within the Queenstown Lakes District are heavily reliant on the surrounding transportation network. Any change that occurs to this network can have a drastic impact upon the people inside the district.

The movement of people is an obvious use of the transportation network within the Queenstown Lakes District and is also the reason that the district maintains a functioning economy. Isolated within the mountain ranges of the Southern Alps the only way into or out of the district is via land or air. Over 3000 people come into the district each year often to experience the wide variety of tourist adventures that the district offers. Two hundred visitors arrive via air and one hundred reach the district via the road. But transportation is really much more than the movement of people; it is also the movement of goods and services.

Figure 33: The lower Shotover River Bridge is the primary access route into Queenstown.

If the transportation network within the Queenstown Lakes District is disrupted people will eventually find that they are cut off from food, supplies (such as medicines, equipment etc) essential services and just about everything else needed to survive. Equally important, wastes would not be able to be properly removed and would likely build up and foster disease. In an urban area with few other acquisition options, increasing hunger, poverty and stress may arise.

LAND TRANSPORT

The most dominant form of transportation in the Queenstown Lakes District is by land. People move about under their own power, either by walking or by other forms of human-powered transportation such as the bicycle. People also occasionally use domestic animals as a means of transportation. The most common forms of land transportation however involve motorcycles, cars or trucks that move people and freight quickly and efficiently throughout the district.

- ***Roading Network***

  To move people and freight quickly and easily throughout the district a transport medium has been created, this medium is made from bitumen and tar and is known as a road. The Queenstown Lakes District is almost totally reliant on the roading network to deliver freight and other supplies to communities as much of the district has no direct rail access and only very limited air freight capacity.

  The roading network in the Queenstown Lakes District can be split into three different systems: state highways, local roads and special purpose roads. State highways are generally roads that form part of the integrated national network of roads that are strategic inter-district routes connecting locations of national significance (for example, large population centres, major ports and airports and major tourist areas) Special purpose roads cater for a high proportion of tourist traffic and are generally those that are being considered for becoming a state highway. All other roads are local roads controlled by territorial authorities.

  The state highways in the district include: State Highway 6 from Haast at the top of the district to Kingston at the bottom of the district via Frankton Flats. State Highway 6a from Frankton to the Park Royal end of Shotover Street. State Highway 84 from State Highway 6 at Mount Iron to Ardmore Street, Wanaka. State highway 8a from State Highway 6 just north of Luggate to State Highway 8 just south of Tarras. Local Roading in the district consists of more than 800km of formed roads (of which over 400KM are sealed), including 91 bridges.

Figure 34: Shotover River Bridge

Bridges in the Queenstown Lakes District provide some of the most the critical links over what could be described as some of the most intense terrain in New Zealand. Bridges close the gaps over steep canyons as well as providing access over a number of river crossings. Unfortunately the link that bridges create make the consequences of bridge damage that much more disrupting to the transportation network. Important bridges in the district to highlight include: the Edith Cavell Bridge (figure 34) and the Lower Shotover Bridge. Arthurs Point Bridge, the twin bridges over the Kawarau River, the Kawarau Bridge at the outlet of Lake Wakatipu and the Albert Town Bridge.

Figure 35: GIS Map of the roading network in the district, highlighting the major bridges.

Freight and supplies come into the district daily via truck to various supermarkets, warehouses and other retailers. Supplies come from either Dunedin or Invercargill and takes roughly 2 - 3 hours. Another resource that is delivered into the district via the roading network is fuel. Fuel itself is considered as a lifeline because of the importance it holds for other services. For example emergency services need fuel for their vehicles, utility services need fuel for back up generators, fuel is also needed for other aircraft and heavy duty construction equipment and much more.

Petroleum products are delivered from bulk tankers that are operated by Silver Fern Shipping Ltd twice a month from the Marsden Point Refinery. A typical run would unload fuel at Timaru, Dunedin and Bluff. The fuel would then be loaded on to tanker trucks and distributed throughout the district. The Queenstown Lakes District is generally supplied with fuel out of Bluff however it is not uncommon to see them delivered out of Dunedin when storage tanks are low.

- ***Railroad Network***

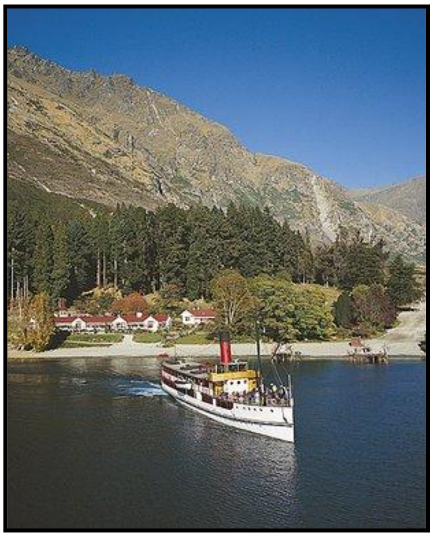
  The railroad network in the Queenstown Lakes District is extremely limited. In fact it only consists of 14km of preserved track that is only used to transport tourists to Fairlight and back on a vintage steam train known as the Kingston Flyer (figure 36).

Figure 36: Satellite image of Kingston illustrating the route of the Kingston Flyer (Source: Google Earth)

WATER TRANSPORT

In the Queenstown Lakes District water transportation is used everyday. It is particularly popular with tourists who experience recreational activities such as Jet boating or rafting and scenic tours such as a trip on the vintage steamship the TSS Earnslaw. Residents that own their own boat sometimes use it to collect supplies from stores located across the lakes otherwise they use it for recreational purposes.

Water transportation is widely used on the glacier lakes with Lakes Wakatipu, Wanaka, and Hawea all having permanent jetty berths available. Most lakes in the area also have boat ramps. In the event of a major disaster these major waterways may provide access to areas that have been isolated from road-slips. It may even prove vital in the transportation of goods and services throughout the district.



The township of Kingston was once a major transit link for the regions goldfields. People and supplies were brought up from the south by rail or wagon and then ferried across the lake on steamships and barges. For a long time this access route provided the most convenient way of getting goods and services into the district. Assuming the wharfs are still usable following a disaster this route may once again become a critical lifeline to communities around the lake that have become isolated.

Figure 37: The 'lady of the lake' TSS Earnslaw leaving Walter Peak Station

AIR TRANSPORT

The fastest way into and out of the Queenstown Lakes District is by air. Aeroplanes and helicopters are abundant and widespread in the district due to the high levels of tourism in the region. Currently there are two airports in the district located in Queenstown and on the outskirts of Wanaka. Queenstown airport is essentially the main airport as most commercial flights land there. Wanaka acts more as a supporting airport and although it is used for some commercial flights it is mostly used for recreational activities such as sightseeing flights. During a major disaster such as an earthquake air transportation will become a critical link in the provision of supplies and the transportation of people

QUEENSTOWN AIRPORT

Queenstown Airport is commonly known as the gateway to the scenic south of New Zealand. It is located on a gently sloping alluvial outwash fan 8km away from central Queenstown. To the west some 400m from the end of the runway is the Frankton Arm end of Lake Wakatipu. The Kawarau River that drains Lake Wakatipu is located to the south of the airport along with the glorious Remarkables mountain range that overlooks the airport. To the northeast the land slowly rises and just before we reach the mountainous Crown Range we strike Lake Hayes. With the continued development in the area the airport now lies in a growing urban area on soils that are not of high quality being shallow and situated upon alluvial gravels that are prone to liquefaction (figure 38).

Figure 38: Photograph of Queenstown Airport situated on an alluvial fan. In the foreground is the suburb of Frankton and in the background the Shotover River. This area is particularly susceptible to liquefaction.

Queenstown Airport has a single sealed runway (05/23) approximately 1911m in length capable of landing 737 aircraft. It also has a grass runway capable of aircraft that weigh up to 5,700kg. Despite its remote setting it is one of the busiest domestic airports in New Zealand with 600,000 passengers passing through it a year and 55,000 aircraft movements per year including heavy jets & turbo props, sightseeing aircraft, general aviation and helicopters.

The majority of scheduled flights are domestic, with a few international flights weekly to Sydney. The winter ski seasons are busy with extra international flights being flown by both Qantas (Boeing 737-800's) and Air New Zealand (Airbus A320's). Weather permitting, there is substantial daily charter traffic of light aircraft (mostly Britten-Norman Islander and Cessna's) to Milford Sound and on sightseeing trips. Helicopters are also very active.

WANAKA AIRPORT

Figure 39: Wanaka Airport looking east (Source: QLDC, 2002)

Wanaka airport (figure 39) is located on a flat elevated river terrace to the east of the Clutha River. The terrace drops away steeply to the SE some 500m from the end of the existing runway. The Clutha River is below the terrace to the east and the airport is screened from the township of Luggate by high ground leading to Mount Barker and by a complex of terraces. To the north is farmland. The site of Wanaka airport was judged in technical evaluation as the most suitable airport site in the region not only because it is located away from populated urban areas, but also because of its topographical and climatic advantages. The airport lies in an open rural locality where the terrain in the immediate vicinity of the runways is flat. The soils are not of high quality, being Luggate shallow sandy loam. The airport has frontage and vehicular access to State Highway 6 (SH6)

Wanaka Airport has two runways. The main runway (11/ 29) is paved and is 1200m long by 30m wide. Immediately adjacent on the NE side of the main runway there is a parallel grass runway. In general, the majority of aircraft use the main runway, although the grass is used by smaller and vintage aircraft – particularly for landing. The two runways are currently too close to allow simultaneous operations. The airport currently operates as a non-certificated airfield. This means that Civil Aviation Rules place the responsibility on the operator of an aircraft to ensure that the airport is suitable for their particular aircraft. A non-certificated status also precludes the operation of scheduled flights for aircraft with seating capacities of 30 persons or over.
Current airfield operations at the airport include a daily Air New Zealand scheduled flights with Beech 1900D aircraft from Christchurch. Flight seeing (Britten Norman Islander and Cessna); Helicopter flight seeing, training and commercial operations; Tandem sky-diving flights (Cresco and C180 aircraft) including the landing of parachutists on the airport. The bi-annual Warbirds over Wanaka air show also sees a range of military aircraft using the airfield such as the Hercules C130, Iroquois, Tiger Moths and P51 aircraft.

EMERGENCY SERVICES

Emergency services are organisations that ensure public safety by addressing different emergencies. Some agencies such as Civil Defence exist solely for addressing certain types of emergencies while others (police, fire, ambulance) deal with everyday emergencies as part of their normal responsibilities. The availability of emergency services depends heavily on location and nature of the emergency.

Effective emergency management requires agencies from many different services to work closely together and have open lines of communication. Individually each organisation has their own set of protocols but when it comes to managing emergency situations comprising of a range of emergency services working together, a standardised management structure should be used. In New Zealand to ensure effective management and communication among emergency service organisations a set of management principles have been developed. This management structure is called CIMS (Co-ordinated Incident Management Structure)

CO-ORDINATED INCIDENT MANAGEMENT STRUCTURE (CIMS)

CIMS is designed primarily to improve the management of the response phase to emergency incidents through better coordination between the major emergency services (Fire, Police, Ambulance and Civil Defence) and between the many other organisations which also have a role in mounting an emergency response. CIMS can be applied to any emergency situation, from car accidents to large scale disasters. CIMS works by providing:

- A standardised model for command, control and co-ordination of a situation by using common terminology for roles, functions and facilities.
- Modular organisation in which the first arriving officer becomes the incident controller.
- Integrated communications where standard operating procedures, common frequencies and terminologies are used to ensure clear concise communication between all affected parties.
- The use of a consolidated incident action plan which is written at the time of the incident to ensure that all services are aware of the roles that they play in response to an emergency and that there is a manageable span of control (defined as the number of functions one person can manage effectively).
- Comprehensive resource management, which ensures that the resources available are used in the most efficient manner.

CIMS aims to build a more proactive incident management response system that will increase efficiencies through better coordination of resources. It will also reduce the risk of service overlap and potential confusion at emergencies through poor understanding and inadequate coordination. This report uses the principles of the CIMS structure to describe the major functions that the major emergency services will perform during an emergency. Unfortunately specific plans for disasters can not be developed due to the wide variability and unpredictable nature of the hazards. During a disaster the major response agencies will need to meet and write an incident management plan to address specific situations.

CIVIL DEFENCE

Civil Defence is a nationwide network of central and governmental agencies, community organisations and volunteers. The purpose of Civil Defence is to educate and assist people to be prepared in an emergency. To many people's disbelief, an army of dedicated Civil Defence people trained, equipped and waiting to be deployed in an emergency does not exist.

In the Queenstown Lakes District there are less than 50 people, consisting of experts and volunteers dedicated to emergency response. These personnel are not specialists in the area of emergency management; they come from varying backgrounds from law enforcement and medicine to council staff and members of the public. Although it would be good to think that they would all respond in a time of crises the reality is, that many would be unavailable. In fact, scenario planning models suggest that of the total number of volunteers only one quarter would respond to a disaster; meaning of the 50 people in the Queenstown Lakes District, only 12 would be available.

A Civil Defence emergency will be declared by the Mayor if an extreme event occurs which endangers life and property and local emergency services are unable to cope.

NATIONAL CRISES MANAGEMENT CENTRE (NCMC)

Following a declaration of Civil Defence emergency a national crises management centre may be established, depending on the level of activation and the demands dictated by the event. With respect to the Queenstown Lakes District, the NCMC will probably be only set up in response to a major earthquake. The purpose of this centre will be to monitor and assess the event by collecting, analysing and disseminating information collected from local civil defence groups.

The NCMC is a secure, centralised facility below ground located underneath the Beehive (Government Buildings) in Wellington. The facility is designed to withstand the effects of an earthquake and other local disasters and service failures. It is also self sustainable with emergency medical, water and power supplies, independent telecommunication systems, fully equipped operation areas and sleeping accommodation for up to 100 persons at a time.

Figure 40: NCMC operations room

The NCMC is staffed by Ministry of Civil Defence and Emergency Management personnel and liaison officers from other relevant government and support agencies The NCMC is responsible for co-ordinating national and international support to an affected area during a state of emergency.

GROUP EMERGENCY OPERATION CENTRES (GEOC)

The GEOC is the main facility from which they will monitor, support, co-ordinate and direct group wide national resources during an emergency. The GEOC will be located at the Otago Regional Council in Stafford St, Dunedin. Should the Group Emergency Operations Centre at the Otago Regional Council be inaccessible or inoperative for any reason, the functions of the Group Emergency Operations Centre may be provided either from the Dunedin City Emergency Operations Centre, situated in Moray Place, Dunedin, or any another Emergency Operations Centre.

The principal function of a Group Emergency Operations Centre is to co-ordinate the resources and support given by the government throughout the Otago region and neighbouring Civil Defence Emergency Management Groups. The Otago region consists of the Queenstown Lakes, Central Otago, Waitaki and Clutha Districts and Dunedin City. With respect to the Queenstown Lakes District, the GEOC will probably be only established in response to a major earthquake, a local earthquake or a major flooding event.

If sufficient resources are not available within the Otago Civil Defence Emergency Management Group area during a state of emergency, the GEOC may request support from neighbouring GEOC's or the NCMC

LOCAL EMERGENCY OPERATION CENTRES (EOC)

The Local Emergency Operation Centre is located at the Civic Centre, 10 Gorge Road, Queenstown. These premises are designed to resist the effects of an earthquake and should remain operational under other emergency conditions. However should these offices be uninhabitable during an emergency there are designated alternate facilities.

The EOC has telecommunication equipment and full electricity generation capability. Personnel appointed to the EOC are drawn from Nominated council and contractor staff, volunteers appointed by the council and specialist advisors. The EOC's are responsible for the co-ordination of local emergency services and the resources and support given by the GEOC. Other principle functions include:

- Arranging community welfare, support facilities and services.
- Monitoring events and altering responses as required.
- Receiving, assessing and disseminating information for local emergency services and response agencies.
- Ensuring communications are in place with key local emergency services and response agencies.
- Providing information to the media and the public about the event and the local response.
- Ensuring efficient recovery preparation and implementation.
- Providing regular updates of information to the Group Emergency Operations Centre.

Figure 41: Civil defence co-ordination centre located at the council offices on Ardmore Street.

If sufficient resources are not available within the Queenstown Lakes District during a state of emergency, the EOC may ask for support from the Otago GEOC or neighbouring GEOC's

To enable and extend control, the district has a Civil Defence Co ordination Centre located at the council offices, 47 Ardmore Street, Wanaka. The co-ordination centre has similar functions as the EOC but will operate under the direction of the EOC located in Queenstown.

COMMUNITY SECTOR POSTS

Sector Posts are community gathering points where assistance can be provided to those adversely affected by an emergency. All civil defence posts are provided with first aid kits which will enable assistance to be provided for minor injuries. The primary means of communication will be through the telephone system, however, hand held radios will be provided at the onset of an emergency event if communication lines have been severed.

Queenstown Civil Defence posts will communicate with the Queenstown EOC and Wanaka Civil Defence Posts will liaise with the Wanaka Civil Defence Co-ordination Centre. The Wanaka Civil Defence Coordination centre as well as Civil Defence posts will utilise resources made available by local people, but should these prove inadequate contact should be made with the Queenstown EOC. When additional resources have been requested, they will be allocated with respect to the overall priority for response needs over the entire district, region or country.

Queenstown Sector Posts include:

- Aspen on Queenstown, Fernhill Road
- Queenstown Primary School, Robins Road
- Presbyterian Church, McBride Street
- Kelvin Heights Golf Club, Peninsula Road
- Arrowtown Primary School, 9 Chalmers Pl
- Glenorchy Primary School, Oban Street
- Kingston Fire Station, Kent Street

Wanaka Sector Posts include:

- Mount Aspiring College, Plantation Road
- Hawea Community Centre/Bowling Club, Capell Avenue
- Albert Town Lodge, Corner Kingston St and SH6
- Luggate Hall, Corner Hopkins St and SH6
- Makarora School, Rata Road

NEW ZEALAND POLICE

Police in the Queenstown Lakes District have a responsibility to serve the community by reducing the incidence and effects or crime, detecting and apprehending offenders, maintaining law and order and enhancing public safety. There are two local police stations in the district, one in Queenstown and the other in Wanaka. Together they provide services throughout the district 24 hour a day, 365 days a year. The types of services they provide range from 111 emergency services to firearms safety and licensing to road policing and theft.

Figure 42: Photo of a police car patrolling the highway.

In the event of a disaster the police, due to their 24 hour availability and day-to-day responsibilities will be required to accept the initial responsibility for the management of the disaster including the co-ordination of initial responses. A serious emergency generally creates complex problems for the maintenance of law and order and the performance of recognised police functions. Thereby, if emergency services are unable to cope with the situation a state of civil defence emergency will be declared and responsibility will be transferred to the Queenstown Civil Defence Emergency Operation Centre. Generally in the lead up to a declaration the police have kept civil defence informed of the situation so this transition should be smooth.

FUNCTIONS

During a state of civil defence emergency the police are likely to be overwhelmed by the number of callouts they receive. Therefore decisions will have to be made regarding the priority of each job. In general, priority will always be given to those jobs involving the protection of lives and/or property. After police are sure that they have taken every measure to ensure that lives and property are out of danger they can resume there other responsibilities that are listed below in order of priority:

1. Maintain Law and Order.
2. Take all measures within their power and authority to facilitate the movement of rescue, medical, fire and other essential services.
3. Help distribute civil defence warning messages.
4. Assist the Coroner (as required by the Coroners Act, 1988) by identifying the dead and notifying the next of kin and if necessary, undertaking appropriate inquiries, if the death is considered suspicious
5. Assist in the registration of evacuees and the location of missing persons
6. Control access into and out of a disaster/evacuated area to assist in the efficient response of emergency services

7. Ensuring the security of the civil defence emergency operation centres, all hospitals or emergency medical triage units, evacuated areas and other areas as requested by the EOC.

STRUCTURE

During a state of emergency, Police will retain their own command structures and will continue to operate from local police stations. However, a police liaison officer must remain available at all times at the Queenstown EOC. This will ensure that communications are maintained between the police and Local Emergency Operation Centres during a state of emergency. Communications will be by the normal telephone network, or by VHF radio supplied by the Police. Police operational procedures will follow the New Zealand Coordinated Incident Management System (CIMS).

Figure 43: Queenstown Police Station located along Camp St

Police personnel will be activated through the normal police call out system and if police reinforcements are required they will be sought through normal police channels. Where difficulty is experienced by the NZ police in obtaining essential supplies and services a request for assistance should be lodged through the EOC. If deemed necessary, police may utilise the resources of registered security firms for appropriate tasks.

NEW ZEALAND FIRE SERVICE

The fire service in the Queenstown Lakes District is comprised of three independent services: the urban fire service which is made up entirely of voluntary fire fighters, the rural fire service which is a joint venture by the district council and the Department of Conservation and the airport rescue fire service at Queenstown airport. Together these services have the responsibility of reducing the incidence and consequences of fire in the district while also providing a professional response to other emergencies.

The urban fire service (figure 44) is made up of four fire stations located in Queenstown, Frankton, Arrowtown and Wanaka. Fire fighters are capable of responding to a wide variety of events such as floods and meteorological hazards where fire fighters help pump out water from flooded buildings and secure roofing and other building material battered by the weather. Fire fighters also play a major role at the scene of motor vehicle accidents and medical emergencies. Fire fighters also help people who are trapped, such as in accidents on building sites. Some personnel are trained in urban search and rescue and would be useful at the scene of an earthquake or complete building collapse. Finally fire fighters are also capable of cleaning up hazardous substances when spilled.

The rural fire services are primarily responsible for controlling outbreaks of vegetation fires and taking measures to prevent the outbreak of fires. In the Queenstown Lakes District there are two rural fire authorities operated by the District Council and the Department of Conservation. The council rural fire service also takes primary responsibility for residential fires and rescues within the townships of Kingston, Glenorchy and Makarora where they are based. During a major disaster where water supply has been temporarily cut off rural fire authorities may be able to assist in the distribution of water supplies by tanker until the piped network is re-established.

The airport rescue fire service is operated by Queenstown Airport Corporation and is primarily responsible for controlling outbreaks of fire on the airport and maintaining flight operations by taking measures to prevent the outbreak of fires. During a disaster these services are capable of providing assistance in fire fighting, rescue and water transport. They would be primarily suited to providing resources at emergency landing zones and if not in use there may be helpful in distributing water if the water supply system was damaged.

Figure 44: Fire at a central Queenstown grocery store, the blaze later spread to a jewellery shop (Source: The Press).

FUNCTIONS

The purpose of the New Zealand Fire Service during a state of civil defence emergency is to provide effective co-ordination and use of fire fighting service to local communities. During a state of civil defence emergency the fire service are likely to be overwhelmed by the number of callouts they receive. Therefore decisions will have to be made regarding the priority of each job. In general, priority will always be given to those jobs involving the protection of lives and/or property. After fire fighters are sure that they have taken every measure to ensure that lives and property are out of danger they can resume there other responsibilities that are listed below in order of priority:

1. Control, contain and extinguish fires using practical fire fighting methods.
2. Provide fire fighting assistance to other fire fighting units if the situation takes priority over initial responsibilities such as when life and safety are threatened (e.g. rural and airport appliances may assist the NZ fire service when they are not in use or a priority)
3. Contain hazardous substance releases and spillages;
4. Rescue trapped persons from fire or other emergencies;
5. Establishing specialist fire protection at temporary aircraft/helicopter landing sites.
6. Assist in the transmission of public warning of an impending emergency by sounding a fixed and/or mobile siren at the request of civil defence.

7. Limit the damage by the salvaging essential resources from endangered locations;
8. Redistribute water for specific needs - health and hygiene requirements of stricken areas. (Note: water supplied through New Zealand Fire Service equipment may not be suitable for drinking without boiling, purifying or other treatment);
9. Temporarily re-establish the piped water supply network through the use of New Zealand Fire Service pumping equipment and hose-lines;

Unlike the police the NZ fire service has no additional pre-declaration responsibilities unless the major event is an uncontrollable fire. If it is the fire service has the responsibility of keeping Civil Defence informed of the escalating situation just in case the situation requires Civil Defence intervention. For example, if it involves the evacuation of communities, threatened by vegetation fires or a possible aircraft crash, in a built up area.

STRUCTURE

During a state of local emergency, fire services will report to the Queenstown EOC. A Fire Service Liaison Officer (appointed fire service advisor or senior fire service officer) must remain available at all times at the Queenstown EOC to provide specialist advice. This will also ensure that communications are maintained between the Fire Service and Local Emergency Operation Centres during a state of emergency. The liaison will also have the responsibility to keep the regional fire commander (based in Dunedin) informed of the situation, taking place within the district.

Figure 45: Queenstown fire station located next to Queenstown Primary school and the electricity substation.

Communications will be by the normal telephone network, or by a VHF radio supplied by the Fire Service. All NZ fire service appliances also carry VHF hand held equipment to enable communication of the emergency services band. Within the district appliances have UHF hand-helds also for fire-ground control. Queenstown Lakes District Council rural fire vehicles are equipped with either civil defence VHF radio, fire service radio or both. Department of Conservation has VHF radio networks that can be accessed from the Queenstown EOC and all have the ability to operate in the emergency services band. The airport rescue fire service is linked to the fire service radio network and has air to ground radio and VHF hand held radio on the emergency services band.

Fire service operational procedures will follow the New Zealand Coordinated Incident Management System (CIMS). Fire service personnel will be activated through the normal fire service call out system and if police reinforcements are required they will be sought through normal fire service channels. Where difficulty is experienced by the NZ Fire Service in obtaining essential supplies and services, a request for assistance should be lodged through the EOC.

ST JOHN AMBULANCE SERVICE

The Ambulance Service (figure 46) within the Queenstown Lakes District is operated by St John and forms part of the St John's Southern Region Service which is based in Dunedin. St John's Mission is to prevent and relieve sickness and injury, and to act to enhance the health and well-being of people of all races and creeds anywhere in New Zealand.

All St John Ambulance Officers are trained under a nationally accredited training programme. After achieving the National Certificate in Ambulance (Patient Care & Transport), officers progress through intravenous and cardiac qualifications to become St John Paramedics. Ambulance Officers who complete the National Diploma in Ambulance (Paramedic) then become Advanced Paramedics. Ambulance officers also have the opportunity to complete the Bachelor of Health Science in Paramedic degree programme.

Figure 46: St John Ambulance Service responding to a traffic accident.

The St John Ambulance Service operates 24 hours a day, seven days a week. Conventional ambulances, four-wheel drive vehicles, rapid response units, motorcycles and helicopters ensure St John will provide aid at any hour of the day in almost any terrain, weather or situation. St John Ambulance services are managed and directed to the site through Emergency Ambulance Communication Centres that despatch and coordinate all the emergency land, water and air ambulance services.

FUNCTIONS

The Ambulance Service's prime role is the saving of life, in conjunction with other emergency services. Specific duties during any local emergency are:

1. Triage, treatment, transport and care of those injured at the scene, either directly or in conjunction with outside agency medical personnel.
2. Setting up of an Ambulance Command Point at major incidents in accordance with the CIMS structure, to provide a management centre for all medical resources.
3. Determination of the priority of evacuation and destination of those injured.

4. Arranging and ensuring the most appropriate means of transporting those injured to the receiving or supporting hospitals.
5. Where appropriate, determination of the main 'Receiving' and 'Supporting' hospitals for the receipt of those injured.
6. Provide regular communication to receiving hospitals of patient numbers/status.
7. Ensuring that adequate medical personnel and support equipment resources are available at the scene.

STRUCTURE

The day to day management of the ambulance service in the Queenstown Lakes District is managed by the District Operations Manager who is based in Alexandra. Responsibilities extend throughout the Queenstown Lakes and Central Otago Districts. During a state of emergency the control and co-ordination of the St John Ambulance Service will be the responsibility of the Medical Manager.

The Medical Manager will be the person currently holding the position of Doctor at the Wakatipu Medical Centre or an appointee, who will control and co-ordinate all the medical activity and resources in the District. The Medical Manager or appointee will need to keep in constant contact with Queenstown EOC. It is thus preferable that an appointee is selected as the District's only doctor is likely to be overwhelmed.

Communications will be the normal telephone network, or by a VHF radio supplied by St John. The ambulance radio net is the primary medical communications system. Communications will be coordinated through the St John communication centre. The ambulance radio net is compatible with the civil defence radio net.

HOSPITALS AND HEALTH SERVICES

The purpose of hospitals and health services is to provide the most effective treatment for injured and distressed people during an emergency through the integration of all medical resources in the community. The normal responsibilities of health providers are not changed due to a state of emergency. Wherever possible, the normal system for the movement of casualties and their treatment and documentation will be used and health professionals will continue to work using standard procedures and in familiar surroundings to the greatest extent possible.

If available resources prove inadequate in a disaster, the establishment of emergency medical units may be required. Emergency medical units are temporary treatment sites in the community where the injured can be received, triaged then treated and discharged or held before being forwarded to hospital. If required an emergency medical unit may be established at the St John Ambulance headquarters at Frankton.

Communications will be the normal telephone network, or by a VHF radio supplied by St John. An ambulance radio is installed at Lakes District Hospital.

Figure 47: Lakes District Hospital in Frankton near Queenstown.

FUNCTIONS

Lakes District Hospital (figure 47) is situated on Douglas Street, Frankton, near Queenstown and serves the entire Queenstown Lakes District. The hospital has 22 beds, a mix of maternity, elderly and acute medical. Services care. Services are provided by registered nurses and the house doctor. Lakes District Hospital has level 2 emergency services meaning the hospital can provide assessment and stabilisation of any ill or injured patients but patients will need to be transferred to another hospital as soon as possible. Pharmaceuticals are supplied via Southland Hospital twice weekly.

The Queenstown Lakes District Hospital provides medical care for the entire district; at the most it may be able to handle up to 30 patients at a time… in peak tourist seasons the population of the district can reach up to 20,000 people. In the event of a major disaster, there is no doubt that the hospital will be overwhelmed with people and realistically there just won’t be enough medical staff or beds to accommodate them all. It will be the medical manager’s responsibility for making sure that hospital resources and facilities are being used as efficiently as possible and if necessary is responsible for establishing, controlling and maintaining alternative hospital facilities. Buildings designated as being suitable for auxiliary accommodation include the St John Ambulance Rooms, Douglas St, Frankton which can handle 20 to 60 patients and the events centre, SH6, Frankton, which can accommodate in excess of 60. However, during an event that injures thousands of people the medical services in the district create a high vulnerability

ADDENDUM

5.3.2 EMERGENCY RESPONSE

The following list is a general description of responses that will need to be undertaken during a disaster. The list has been written in order of priority; however, some tasks can be undertaken simultaneously. It is important to note that these response procedures should only be used as a general strategy as there are multiple factors that can influence management decisions.

LIFELINE	GENERAL DUTIES	LANDSLIDE SPECIFIC TASKS
ELECTRICITY	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the electricity system Identification & management of other damaged components	Components likely to be damaged as a result of a landslide include distribution lines and the low voltage network. Any components affected by the slip will need to be isolated and may need to be turned off until it is safe to repair damaged components.
TELE-COMMUNICATION	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the telecommunication system Identification & management of other damaged components	Components likely to be damaged as a result of a landslide include fibre optic transmission lines, copper cabling distribution system, maybe some communication masts/towers.

WATER SUPPLY	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the water supply system Identification & management of other damaged components	Components likely to be damaged as a result of a landslide include water distribution networks and some reservoirs. Depending on the damage to the water supply network, measures may need to be employed to conserve water. (e.g. rationing, filling of miscellaneous storage tanks). This however is highly unlikely due to the redundancies built into the system.
WASTEWATER	Identification & management of damaged components that are threatening life and/or property Identification & management of damaged components that are causing adverse affects to other lifelines Identification & management of damaged components severely affecting operation of the wastewater system Identification & management of other damaged components	Components likely to be damaged as a result of a landslide include the sewage reticulation network. Sewage that has spilled into the environment or onto streets will require containment & cleaning up
TRANSPORTATION	Identification & management of disruption to the roading network that is hindering emergency response. Identification & management of disruption to the roading network	Components likely to be damaged or severely disrupted as a result of a landslide include roads.

6.5 RANKING OF SCENARIOS

Scenarios in this thesis were used to further illustrate the vulnerability of lifelines in the Queenstown Lakes District. From this information we can conclude that each scenario will have its own set of challenges and associated responses. Even though each hazard should be dealt with separately a certain amount of multi-hazard analysis should also be undertaken. To help planners and emergency managers prepare for the next disaster, it is important to discuss the relative importance of each scenario.

Ranking of the scenarios must be done carefully as each hazard has its own set of individual characteristics such as the frequency at which it occurs and the magnitude of the damage that it can create. For example an earthquake of relatively low frequency can have a high magnitude whereas flooding with a higher frequency of occurrence has a relatively lower magnitude. To be able to rank these hazards based upon both of these factors will be difficult and therefore the relative importance has been discussed based on each.

Although the result of this discussion will determine a relative importance for each scenario it does not predict which event will occur next. Therefore it is highly recommended that emergency planning takes into consideration all scenarios rather than just focusing on the most important.

6.5.1 RANKING OF SCENARIOS BASED ON FREQUENCY

The frequency at which these hazards occur can vary considerably as they are calculated based on past incidences. Factors such as urban growth and climate change can influence the timing of disasters not to mention the implementation of mitigation measures and planning policies. However based upon current predictions the ranking is as follows:

1. Flooding
2. Earthquake
3. Storm
4. Landslide

Flooding in the Queenstown Lakes District generally occurs every couple of years and therefore was the obvious choice for being placed at the top of the list. The second most important scenario is an earthquake. This may seem a surprising choice as major earthquakes in the region only occur on average every 200 years. However it was placed here based on the fact that the last major earthquake occurred nearly 200 years ago. Thus the probability of one occurring in the very near future is quite high.

Storms that occur with enough force to damage lifelines generally occur on average once every decade and therefore was ranked third. The final scenario is landslide. Although mass movements occur in the district quite frequently they are generally located away from urban areas without consequence to lifelines. The frequency at which a landslide occurs within a populated area is lower than one a century and therefore was ranked as the least important.

6.5.2 RANKING OF SCENARIOS BASED ON MAGNITUDE

The magnitudes of the scenarios described in the previous chapter are supposed to represent the worst case. The relative importance of each scenario is based upon its overall effect on the lifelines in the district. Again the magnitude of the scenario may vary depending on the extent of the natural hazard, the relative importance of affected lifelines and the communities understanding of the hazard. But based upon current scientific understanding the scenarios are ranked as follows:

1. Earthquake
2. Landslide
3. Storm
4. Flooding

An earthquake is undoubtedly the worst scenario in terms of damage that it can inflict on multiple lifelines. Earthquakes not only can catastrophically destroy lifelines they can damage them across a wide area. Storms and landslides can be ranked second equal as they contrast one another (i.e. Landslides have a higher magnitude than storms however, a landslide only affects small area whereas a storm can damage lifelines across a large region). Flooding is considered the least important scenario in terms of magnitude. This may be due to outside influencing factors such as mitigation measures and planning policies that have been implemented over recent years. This hazard management has decreased the magnitude of a future event and that is the primary reason why flooding has been ranked below landslides and storms.

6.5.3 OVERALL RANKING OF SCENARIOS

Taking into consideration both magnitude and frequency an overall ranking of scenarios can be attempted. It is important to bare in mind that this ranking is based upon a number of assumptions and hypothetical situations and therefore should only be used a rough guide and equal thought should be placed across all scenarios. The overall ranking is as follows:

1. Earthquake

2. Flooding
3. Storm
4. Landslide

Earthquakes are considered the most important scenario based upon the predicted occurrence of the next earthquake and the potential effects it may have over multiple lifeline. Flooding is the most frequent disaster in the Queenstown Lakes District and based primarily on this, it has been ranked second overall. Storms although relatively low in magnitude, they can affect a wide area and therefore have come into position three. Landslides although disastrous have a relatively low frequency and generally only affect a small area and therefore they have been ranked as the least important.

6.6 GIS DATA

The data that was used to create the GIS Hazard Maps in this thesis were reproduced (with permission) from the Queenstown Lakes District Council Hazard Maps Collection. Data was sourced by the council and the Institute of Geological and Nuclear Sciences (GNS). Some of the data that was used in the creation of these maps are approximate values only. Therefore these maps are only to be used as a rough guide. It is recommended that before any further work is undertaken a more detailed scientific investigation of the area concerned should be carried out.

The earthquake hazard map showing the traces of active faults in the region was sourced from the Active Faults Database at GNS. The faults indicated in the map have all ruptured in the last 10,000 years. This does not mean that they will rupture in the future nor does it mean that an earthquake in the future will rupture along these lines. The purpose of this map is to show how fractured and faulted the landscape surrounding the Queenstown Lakes District is and the most likely location for ruptures in the future.

The earthquake hazard map indicating the possible zones of liquefaction in the Queenstown Lakes District was created based upon the underlying geology; the map is highly generalised and should be used cautiously. For example, on the map it shows that the entire alluvial fan of the Shotover River is susceptible to liquefaction. However this is clearly incorrect. This has come as a result of all alluvial areas being highlighted as potentially liquefiable. Although it is true that liquefaction predominantly occurs in alluvium it also depends on a number of other factors such as the water table level (distance from water source) and depth of material etc. It is more likely that the areas susceptible to liquefaction are those surrounding the margins of the large water bodies such as Lake Wakatipu. (i.e. the township of Frankton) It is unlikely that liquefaction will extend through to the airport although an investigation into the fractures on runways after a large earthquake is still recommended.

The mass movement hazard map shows past landslide activity. The Data was sourced from GNS through physical observations. It is understood that land movement in the future is more likely to occur in areas that have moved in the past. Therefore this hazard map is used to show based on this understanding the possible locations of landslides in the future. Data summarises all movement types including rockfalls, landslides, debris flows and avalanches. Mass movements in the future may or may not occur in these locations. The primary purpose of this map was to show how unstable the land around the Queenstown Lakes District has been.